3.10 Geology, Soils, and Seismicity (Including Mineral and Paleontological Resources)

This section describes geology, soils, and seismicity (including mineral and paleontological resources) that could be affected by implementation of the proposed program. This section is composed of the following subsections:

- Section 3.10.1, “Environmental Setting,” describes the physical conditions in the program study area as they apply to geology, soils, and seismicity.
- Section 3.10.2, “Regulatory Setting,” summarizes federal, State, and regional and local laws and regulations pertinent to evaluation of the proposed program’s impacts on geology, soils, and seismicity.
- Section 3.10.3, “Analysis Methodology and Thresholds of Significance,” describes the methods used to assess the environmental effects of the proposed program and lists the thresholds used to determine the significance of those effects.
- Section 3.10.4, “Environmental Impacts and Mitigation Measures for NTMAs,” discusses the environmental effects of the near-term management activities (NTMAs) and identifies mitigation measures for significant environmental effects.
- Section 3.10.5, “Environmental Impacts, Mitigation Measures, and Mitigation Strategies for LTMAs,” discusses the environmental effects of the long-term management activities (LTMAs) and provides mitigation measures for significant environmental effects.

NTMAs and LTMAs are described in detail in Section 2.4, “Proposed Management Activities.”

For a discussion of subsidence caused by aquifer compaction, see Section 3.11, “Groundwater Resources.”

3.10.1 Environmental Setting

Information Sources Consulted

Sources of information used to prepare this section include the following:

- *California Geological Survey Note 36: California Geomorphic Provinces* (CGS 2002a)

- "Quaternary Geology of the Great Valley, California" (Lettis and Unruh 1991)
- *Geology of the Fresh Groundwater Basin of the Central Valley, California, with Texture Maps and Sections* (Page 1986)
- "Status of the Lower Sacramento Valley Flood-Control System within the Context of Its Natural Geomorphic Setting" (Singer et al. 2008)
- "Early Reclamation and Abandonment of the Central Sacramento–San Joaquin Delta" (Thompson 2006)
- *Database of Potential Sources for Earthquakes Larger than Magnitude 6 in Northern California* (USGS 1996)
- *Generalized Soil Map of California* (University of California 1980)
- *Geology of the Sierra Nevada: Revised Edition* (Hill 2006)
- *Geology of the San Francisco Bay Region* (Sloan 2006)

Other public and private publications on California geology were also reviewed and are cited where appropriate.

Geographic Areas Discussed

Geology, soils, and seismicity (including mineral and paleontological resources) are dominated by characteristics and processes that define resource-specific regions, such as geomorphic provinces. These regions tend to cross the boundaries of geographic areas within the study area. Therefore, geology, soils, and seismicity are not discussed separately for the different geographic areas within the study area (Figure 3.10-1). Rather, this discussion is organized by the broad characteristics that distinguish each resource-specific region: geology, geomorphology, seismicity and neotectonics, soil types, soil properties and processes affecting management, mineral resources, and paleontological resources.

The discussion of geology, soils, and seismicity (including mineral and paleontological resources) frequently refers to the divisions of the geologic time scale, including the eras, periods, and epochs of that scale. For context, the general time boundaries of these divisions are as shown in Table 3.10-1.

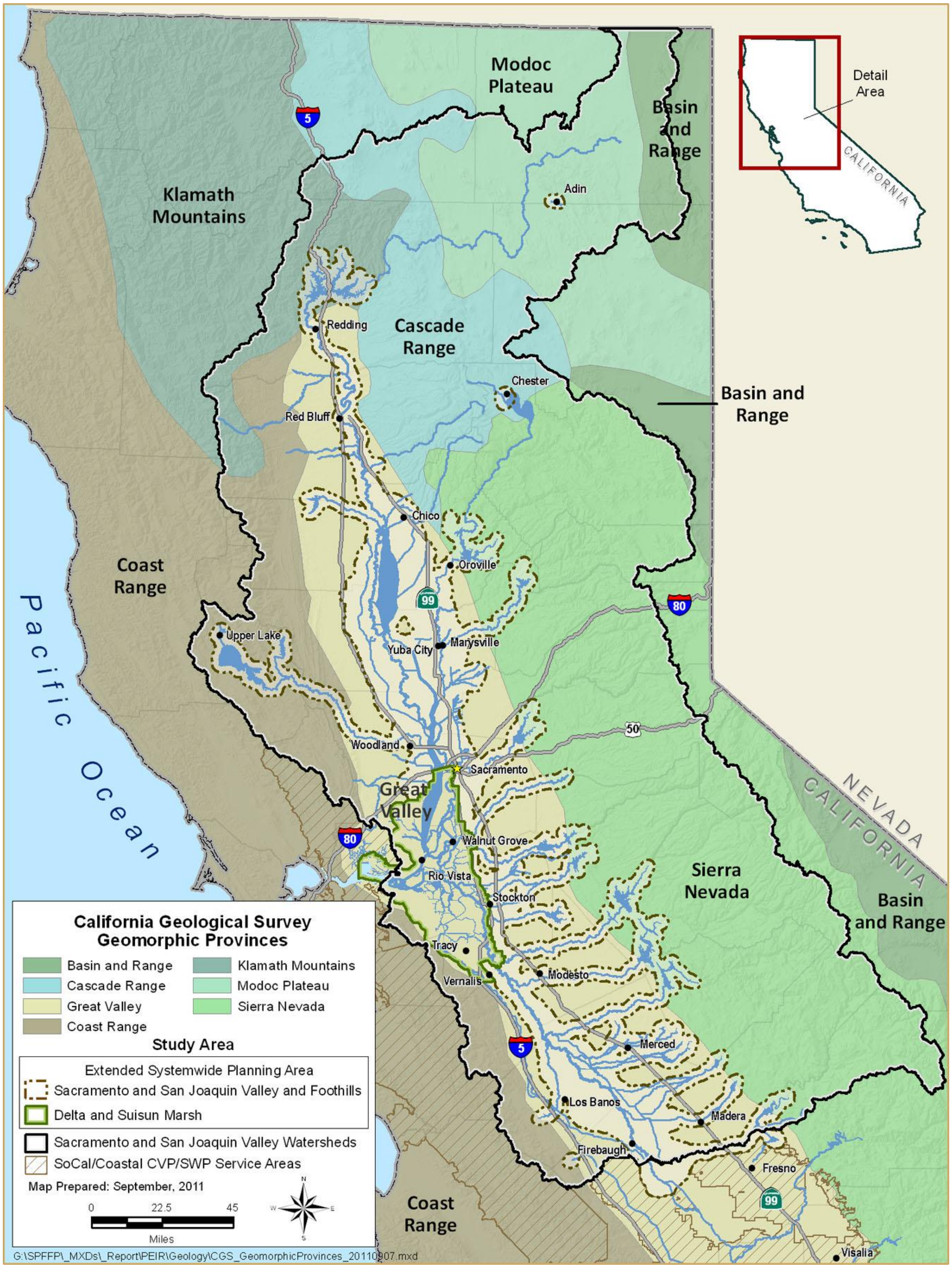

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Figure 3.10-1. Geomorphic Provinces of California Related to the Study Area

Table 3.10-1. Geologic Time Scale

Time Boundary				Estimated Beginning of Boundary	
Eon	**Era**	**Period**	**Epoch**	**Minimum (Ma)**	**Maximum (Ma)**
Phanerozoic	Cenozoic	Quaternary	Holocene	0	0.01
			Pleistocene	0.008	2.6
		Tertiary	Pliocene	1.6	5.3
			Miocene	5	24
			Oligocene	23	38
			Eocene	33.7	57.8
			Paleocene	54.6	66.4
	Mesozoic	Cretaceous	Late	65	99
			Early	90	145.6
		Jurassic	Late	138	163
			Middle	157.1	187
			Early	178	213
		Triassic	Late	205	235
			Middle	227	242
			Early	240	250
	Paleozoic	Permian	Late	240	258
			Early	256	295
		Pennsylvanian	Late	280	304
			Middle	304	311
			Early	311	330
		Mississippian	Late	314	340
			Early	340	362.5
		Devonian	Late	354	382.5
			Middle	370	394
			Early	386	418
		Silurian	Late	408	424
			Middle	0	0
			Early	421	443
		Ordovician	Late	435	463.9
			Middle	458	478
			Early	470	510
		Cambrian	Late	491	523
			Middle	505	540
			Early	518	570
Precambrian				540	4560

Source: Wilson 2001

Key:
Ma = millions of years ago

Geology

Different geologic processes acting on various rock types over millions of years have created geologically different areas within California. Each area is considered a geomorphic province, and 11 are present, at least partly, in California. From north to south, these geomorphic provinces are the Coast Range, Klamath Mountains, Cascade Range, Modoc Plateau, Great Valley, Sierra Nevada, Basin and Range, Mojave Desert, Transverse Range, Peninsular Range, and Salton Trough provinces. The following discussion characterizes parts of the first six provinces listed. The other five provinces are outside the study area or would not be affected by implementation of the proposed program. Figure 3.10-1 shows the geomorphic provinces in California related to the Sacramento and San Joaquin Valley watersheds. The six geomorphic provinces within the study area are described below.

Coast Range Province The Coast Range Province extends 600 miles from the Oregon-California border in the north to the Transverse Range in Southern California. As the name suggests, the Coast Range Province parallels the California coast along the Pacific Ocean, extending inland 20–80 miles (CGS 2002a).

As described below, the Coast Range Province is dominated by a parallel series of mountain ranges and fault-controlled valleys. The province consists of Mesozoic marine sedimentary and metasedimentary rocks that have undergone intense folding and faulting.

The Mendocino Range in the northern Coast Range Province is one of the longer and higher ranges in this province, with some peaks that reach 6,000 feet. The Diablo Range lies west of the San Joaquin Valley and extends from Mount Diablo southeast to the Kettleman Hills. Mount Tamalpais is the northern extension of the Santa Cruz Mountains, which continue southward down the San Francisco Peninsula to Monterey Bay. San Francisco Bay is a structural depression between the Diablo Range to the east and the Santa Cruz Mountains to the west.

The Salinas Valley, the longest continuous valley in the province, is bounded by the Gabilan Range on the east side and the Santa Lucia Range on the west side (Reclamation 1997). Mesozoic granitic rocks are exposed in these two ranges. Some Cenozoic volcanic rocks are exposed in the Napa and Sonoma valleys and in the Diablo Range east of Hollister. The mountain ranges parallel the faults and lie between major fault systems.

Klamath Mountains Province The Klamath Mountains Province covers about 12,000 square miles of northwestern California between the Coast Range Province to the west and the Cascade Range Province to the east. The Klamath Mountains consist of several individual mountain ranges that trend more northward. These mountains consist of Paleozoic metasedimentary and metavolcanic rocks and Mesozoic igneous rocks. They may be a northwest extension of the Sierra Nevada, although the connection is obscured by the younger alluvial deposits of the Central Valley and the volcanic flows of the Cascade Range and the Modoc Plateau (CGS 2002a, 2002b).

Thompson Peak, located in the Trinity Alps, rises to an elevation of 8,936 feet, making it the tallest peak in the Klamath Mountains. Although the peaks of the Klamath Mountains are lower than those of the Sierra Nevada, some of the higher peaks in the Trinity Alps have been glaciated.

The Klamath Mountains have a very complex geology. The province is formed primarily by several mountain belts: the eastern Klamath Mountains, central metamorphic, western Paleozoic and Triassic, and western Jurassic belts. Between these belts, low-angle thrust faults allow eastern blocks to be pushed westward and upward. The Klamath Mountains consist of up to 40,000 feet of eastward-dipping Ordovician to Jurassic marine deposits. The central metamorphic belt contains Paleozoic hornblende and mica schists and ultramafic rocks. The western Jurassic, Paleozoic, and Triassic belts consist of slightly metamorphosed sedimentary and volcanic rocks (Reclamation 1997; CGS 2002b; Irwin and Wooden 1999).

Cascade Range and Modoc Plateau Provinces The Cascade Range Province and Modoc Plateau Province are presented together because of their geologic similarity. These provinces cover about 13,000 square miles of the northeast corner of California, bordering the Klamath Mountains to the west, the Central Valley to the southwest, and the Sierra Nevada to the south.

The Cascade Range and Modoc Plateau are geologically young provinces with a large variety of volcanic rocks (CGS 2002a, 2002b). The Cascade Range includes recently active volcanic domes, among them Mount Shasta and Mount Lassen in California (Wakabayashi and Sawyer 2001). Mount Lassen erupted intermittently between 1914 and 1917, making it the only California volcano active in the 20th century. Evidence indicates that Mount Shasta erupted during the 18th century. The volcanoes of the Cascade Range extend north to British Columbia.

Cascade Range volcanics have been divided into the Western Cascade series and the High Cascade series. The Western Cascade series consists of Miocene-aged basalts, andesites, and dacite flows interlayered with rocks of explosive origin, including rhyolite tuff, volcanic breccia, and agglomerate. This series is exposed at the surface in a belt 15 miles wide and 50 miles long from the Oregon border to the town of Mount Shasta.

After a short period of uplift and erosion that extended into the Pliocene, volcanism resumed, creating the High Cascade volcanic series. This series forms a belt 40 miles wide and 150 miles long just east of the Western Cascade series rocks. Early High Cascade rocks formed from very fluid basalt and andesite that extruded from fissures to create low shield volcanoes. Later eruptions during the Pleistocene had higher silica content, causing more violent eruptions. Large volcanic domes like Mount Shasta and Mount Lassen had their origins during the Pleistocene (Reclamation 1997; Sherrod and Smith 2000; Wright 1984).

The Modoc Plateau consists of a high plain of irregular volcanic rocks of basaltic origin. The numerous shield volcanoes and extensive faulting on the plateau give the area more relief than may be expected for a plateau. The Modoc Plateau averages 4,500 feet above mean sea level and is considered a small part of the Columbia Plateau, which covers extensive areas of Oregon, Washington, and Idaho (Reclamation 1997).

Great Valley Province The Great Valley Province encompasses the Central Valley, an alluvial plain about 50 miles wide and 400 miles long that is located in the central part of California, stretching from just south of Bakersfield to Redding in the north. Because the Great Valley Province encompasses most of the historical and current floodplain within the study area, it is discussed in more detail than the other geomorphic provinces.

The Central Valley consists of the Sacramento Valley to the north, the San Joaquin Valley to the south, and the Sacramento–San Joaquin Delta (Delta) in the center. The Sacramento Valley and San Joaquin Valley are drained by the Sacramento and San Joaquin rivers, respectively, which flow into the Delta. The Great Valley Province is bounded to the west by the pre-Tertiary and Tertiary semiconsolidated to consolidated marine sedimentary rocks of the Coast Ranges. The faulted and folded sediments of the Coast Ranges extend eastward beneath most of the Central Valley. The east side of the Central Valley is underlain by pre-Tertiary igneous and metamorphic rocks of the Sierra Nevada. The north end is underlain by Tertiary volcanic rocks of the Coast Ranges, and bounded by the pre-Tertiary metavolcanics and granitic and metamorphic rocks, and by the Cenozoic volcanic rocks of the Cascade Range.

Pre-Tertiary marine sediments account for about 25,000 feet of the total amount of sediments deposited in the sea before the rise of the Coast Ranges. Marine deposits continued to fill the Sacramento Valley until the Miocene Epoch and portions of the San Joaquin Valley until the late

Pliocene, when the last seas receded from the Central Valley. After the seas receded, continental alluvial deposits from the Coast Ranges and the Sierra Nevada began to collect in the newly formed Central Valley. The Great Valley Province is characterized by alluvial, continental, and marine sediments deposited almost continually since the Jurassic Period (CGS 2010a).

During much of the Tertiary Period, the Central Valley and the predecessors of the Sacramento and San Joaquin river systems were drained to the ocean through a southern outlet in what is now the Kettleman Hills. As movement along the San Andreas Fault closed this outlet during the late Tertiary Period, a vast inland lake formed in the Central Valley, depositing much of the sediments that fill the Great Valley Province.

Tectonic activity during the Tertiary Period strongly influenced the evolution of the Central Valley. Such activity alternated between trapping water in the San Joaquin Valley or entire Central Valley to form inland seas that deposited marine sediments, and creating openings that allowed water to drain to the ocean at varying locations at different times. Volcanic deposits originating from volcanic activity to the east in the Sierra Nevada also contributed to sediments that filled the Great Valley Province. Alternating marine and continental deposits of Tertiary age underlie much of the Great Valley Province (Page 1986).

During the more recent Quaternary Period, the inland lake that once filled the Central Valley spilled over low-lying land in the Coast Range Province, ultimately carving the Carquinez Strait and flowing through the Bay Area to the Pacific Ocean (Sloan 2006; Hill 2006). Today, the water originating in the watershed of the Great Valley Province collects in the Delta before draining to the ocean through this outlet. The Quaternary Period was characterized by continental sedimentary deposition. The Sacramento and San Joaquin valleys are filled with about 10 and 6 vertical miles of sediment, respectively. The most recent surficial alluvial deposits are mined for aggregate, as discussed below (CGS 2002a).

Tertiary and Quaternary continental deposits in the San Joaquin Valley make up the major aquifer of the valley. These deposits consist of the Mehrten, Kern River, Laguna, San Joaquin, Tulare, Tehama, Turlock, Riverbank, and Modesto formations (Ferriz 2001; Page 1986). The aquifer system is discussed further in Section 3.11, “Groundwater Resources.” These continental rocks and deposits consist largely of coarse-grained material derived from the Cascade Range and Sierra Nevada, but also contain lenses of clay and silt comprising lacustrine, marsh, and floodplain deposits (Page 1986).

The Delta is the central, low-lying region that includes tidally influenced portions of the Sacramento and San Joaquin rivers, as well as the Mokelumne and Cosumnes rivers. Flows conveyed from the Sacramento Valley through the Sacramento River, the San Joaquin Valley through the San Joaquin River, or more directly from the Sierra Nevada through the Mokelumne and Cosumnes rivers converge in the waterways of the Delta. The water and sediment that entered the Delta from its tributary rivers interacted in a complex way, leading to the development of thick layers of organic soils and a dendritic network of channels bordered by natural levees. The natural islands of the Delta were generally slightly elevated marshes subject to ponding or frequent inundation during high tides or flood conditions. Human activities to reclaim the Delta islands, described in “Geomorphology” below, caused the islands to subside and required the natural levees to be fortified and raised (Atwater et al. 1979; Florsheim et al. 2008).

Sierra Nevada Province The Sierra Nevada Province encompasses the mountains of the Sierra Nevada and comprises primarily intrusive rocks, including granite and granodiorite, with some metamorphosed granite and granite gneiss. The province is a tilted fault block nearly 400 miles long, with a high, steep multiple-scarp east face and a gently sloping west face that dips beneath the Great Valley Province (CGS 2002a). To the north, the Sierra Nevada Province is bounded by the Cascade Range and Modoc Plateau provinces. To the south, it is separated from the Transverse Range Province by the Garlock Fault. East of the Sierra Nevada Province, the Basin and Range Province extends east to Utah.

The central Sierra Nevada Province has a complex history of uplift and erosion. The greatest uplift tilted the entire Sierra Nevada block to the west. The high elevation of the Sierra Nevada leads to the accumulation of snow, including the Pleistocene glaciation responsible for shaping much of the range.

Snowmelt in the Sierra Nevada feeds the Sacramento and San Joaquin rivers and their eastside tributaries—the Yuba, Feather, American, Merced, Tuolumne, Stanislaus, and Mokelumne rivers. These large rivers and their smaller tributaries cut through the granitic rocks present in the upper watersheds of the Sacramento and San Joaquin rivers, and through intrusive formations and sedimentary and metamorphosed rocks in the lower watersheds. The metamorphic bedrock in these watersheds contains gold-bearing veins in the northwest-trending Mother Lode that are not present in the more northerly watershed of the Sacramento River or the more southerly watershed of the upper San Joaquin River (CGS 2010a). At the western border, alluvium and sedimentary rocks overtop the Sierra Nevada

Province. Occasional remnants of lava flows and layered tuff are present in the area at the highest elevations.

Geomorphology

The geomorphology of the Sacramento and San Joaquin Valley watersheds is shaped through the relationship of the watersheds with the geomorphic provinces they drain, as described above, and by human activities such as levee construction and maintenance. The Delta’s geomorphology is formed by the combined influences of its tributary watersheds, changes in tides and sea levels, and human activities within the Delta itself (flood protection, land reclamation, agriculture, and water supply activities). This section provides an overview of the geomorphic land types in the Central Valley, followed by a more detailed discussion of the geomorphic setting of the watersheds and the Delta. Geomorphologic processes related to erosion and sedimentation are described separately under “Soil Erosion and Sedimentation” in the “Soil Properties and Processes Affecting Management” section, below.

Overview of Central Valley Geomorphology The Sacramento and San Joaquin rivers and their tributaries flow out of the Sierra Nevada Province into the Central Valley, depositing sediments on the alluvial fans, riverbeds, floodplains, and historical wetlands of the Great Valley Province. The Merced, Tuolumne, Stanislaus, and Mokelumne rivers, major tributaries to the San Joaquin River, flow west from the Sierra Nevada to join the San Joaquin. The Feather River and its main tributaries, the Yuba and Bear rivers, flow west from the Sierra Nevada along with the American River to join the Sacramento River. Each of these rivers lies in a steep, narrow canyon in the Sierra Nevada and foothills, then flows into the Central Valley over broad, open alluvial fans and floodplains.

The Central Valley floor is divided into several geomorphic land types—dissected uplands, low alluvial fans and plains, river floodplains and channels, and overflow lands and lake bottoms:

- *Dissected uplands* consist of both consolidated and unconsolidated continental deposits of Tertiary and Quaternary age that have been slightly folded and faulted.

- *Alluvial fans and plains* are unconsolidated continental deposits that extend from the edges of the valley toward the valley floor. The alluvial plains cover most of the valley floor, making up some of the Central Valley’s intensely developed agricultural lands. Alluvial fans along the Sierra Nevada have high percentages of clean, well-sorted gravel and sand. Fans formed by streams in the Coast Ranges on the west side of the Central Valley are less extensive; these fans tend to be poorly sorted, containing high percentages of fine sand, silt, and clay. As on the west side of the valley, areas between major alluvial fans on the east side of the Central Valley are drained by smaller intermittent streams. Thus, these interfan areas tend to be poorly sorted, with lower permeability than main fan areas. In general, alluvial sediments of the western and southern parts of the Central Valley tend to have lower permeability than east-side deposits.

- *Active river floodplains and historic channels* lie along the major rivers and, to a lesser extent, along the smaller streams that drain into the valley from the Sierra Nevada. Some floodplains are well-defined where rivers incise their alluvial fans. Deposits in these areas tend to be coarse and sandy in the channels, and finer and silty in the floodplains.

- *Lake bottoms* of overflow lands include the historic beds of Tulare Lake, Buena Vista Lake, and Kern Lake, and other less defined areas in the valley trough. Near the valley trough, fluvial deposits of the east and west sides grade into fine-grained deposits. Extensive lake bed deposits are not present in the Sacramento Valley. The San Joaquin Valley has several thick lake bed deposits. The largest lake deposits in the Central Valley are found beneath the Tulare Lake bed, where up to 3,600 feet of lacustrine and marsh deposits form the Tulare Formation. This formation is composed of widespread clay layers; the most extensive is the Corcoran Clay member, which is found in the western and southern portions of the San Joaquin Valley. The Corcoran Clay member is a confining layer that separates the upper semiconfined to unconfined aquifer from the lower confined aquifer.

Gold mining activities in the late 19th and early 20th centuries influenced the geomorphology of the study area, particularly the Sacramento River watershed and the Delta. The watersheds of the Sacramento and San Joaquin rivers and their tributaries in the Sierra Nevada foothills and above were subject to hydraulic and placer mining in the mid to late 19th century, followed by dredge mining beginning in the late 19th century and continuing into the 1960s (Reclamation 2002). Hydraulic and placer mining activities removed and relocated sediment throughout the river systems. Relocating large amounts of sediments from higher in the watersheds to the river channels themselves caused flooding patterns to change. Those changes were frequently combated by constructing and enhancing levees and weirs, particularly in the Sacramento Valley. See “Geomorphology of the Sacramento River Watershed” below and Section 3.13, “Hydrology.”

Several secondary geologic structures are found in the Central Valley. The Red Bluff Arch, located at the northern end of the Sacramento Valley, is a series of northeast-trending anticlines and synclines that together act as a groundwater barrier between the Sacramento Valley and the Redding Basin. East of Colusa in the central Sacramento Valley, the Sutter Buttes—a remnant of a volcanic cone 10 miles in diameter—rise 2,000 feet above the valley floor.

In addition, in the San Joaquin Valley a faulted ridge known as the Stockton Arch extends from the Sierra Nevada to the northern Diablo Range. The faulting and folding of the adjacent Coast Ranges is present along the west side of the San Joaquin Valley in the Kettleman Hills, Elk Hills, Lost Hills, and Buena Vista Hills. The northeast-trending White Wolf Fault is believed to be part of the Bakersfield Arch, which is located in the southern end of the valley.

Many faults and folds are located throughout the Central Valley (see “Seismicity and Neotectonics” below), but most do not act as groundwater barriers or controls. The Red Bluff Arch and Bakersfield Arch are notable exceptions.

Geomorphology of the Sacramento River Watershed Between Shasta Lake and Red Bluff, the upper Sacramento River is bounded and underlain by resistant volcanic and sedimentary deposits that confine the river, resulting in a relatively stable river course. This reach of river is characterized by steep vertical banks; the river is mostly confined to its channel, with limited overbank floodplain areas. Bank protection, primarily rock riprap, has been placed along various sections of the Sacramento River to prevent erosion and river meandering. The river’s meander is limited above Red Bluff.

Downstream from Red Bluff, the lower Sacramento River is relatively active and sinuous, meandering across alluvial deposits within a wide meander belt. The active channel consists of sandy point bars on the inside of meander bends, and is flanked by active floodplain and older terraces. Most of these features consist of easily eroded, unconsolidated alluvium; however, there are also outcrops of resistant, cemented alluvial units such as the Modesto and Riverbank formations. Geologic outcroppings and human-made structures, such as bridges and levees, act as local hydraulic controls and confine movement of much of the lower Sacramento River.

As discussed previously, gold mining activities in the Sierra Nevada were particularly focused in the Sacramento River watershed, and transformed the geomorphology of the lower Sacramento River and its main tributaries. Before gold mining resulted in substantial sedimentation, eventually resulting in construction of the Sacramento River Flood Control Project, floods in the Sacramento Valley were not contained within river channels;

rather, floods spilled over natural levees into a series of lowland basins (James and Singer 2008). Gold mining caused an influx of sediments to steep, narrow foothill canyons. Much of this sediment was deposited far downstream to alluvial fans and basins along the margin of the Sacramento Valley. This sediment influx raised riverbed elevations, in turn leading to increased flooding, particularly along the Yuba, Feather, and Sacramento rivers (James et al. 2009).

Improvements intended to counteract increased flooding intensified; the riverbeds were dredged to remove sediment and levees were constructed incrementally. Early attempts at flood control emulated the flood control system of the Mississippi River, where levees were constructed and fortified to force river flow to remain in the channel, in an effort to force sediment scouring and maintain channel capacity.

In the early 20th century, after this approach led to a series of localized levee failures and overtopping along the Sacramento River and its tributaries, a channel bypass system was adopted. This system, in use today, incorporates many of the valley’s natural flood basins. The system routes excess floodwaters over a series of weirs and through broad, channelized flood bypasses located in historical flood basins, in much the same way that floodwaters were naturally conveyed through the valleys (James and Singer 2008).

Today the geomorphologic characteristics of the Sacramento River and its main tributaries within the valley are dominated by this highly constructed environment. Much of the sediment currently conveyed during high-flow periods originates from legacy tailings fans that were developed in the hydraulic mining era and persist today below most dams and between modern levees in the Sacramento River watershed. These unconsolidated sediment deposits are subject to erosion and transport downstream to the flood bypasses and to the Delta (James et al. 2009). As floodwaters enter the broad flood bypasses, the water spreads across the bypasses and slows, dropping much of its sediment load within the bypass system, particularly at bypass entrances. These deposits increase the stage that the water in the main river channel must reach before flows can be redirected into the bypasses, and may cause backwater conditions in the bypasses that limit their utility. Deposition is particularly acute at river-bypass confluences, such as the confluence of the Sutter Bypass, Feather River, and Sacramento River (Singer et al. 2008). Regular maintenance activities include sediment removal to reduce the effects of sediment on bypass functionality.

The Sacramento River’s flood management system is described further in Section 3.13, “Hydrology.”

Geomorphology of the San Joaquin River Watershed The San Joaquin River immediately downstream from Friant Dam has been simplified from its historic state into a single narrow channel. Large parts of the channel have been altered as a result of aggregate mining, and in- and off-channel mining pits have captured streamflow in some places. Aside from these mining pits, very few side channels or backwater complexes exist along the San Joaquin River, except in one or two locations where permanent channels have established themselves around major in-channel islands or gravel pits. In-channel islands are rarely natural features; instead they have been formed by the hydraulics of breached gravel pit levees. Farther downstream, river terraces gradually merge with the floodplain. By Gravelly Ford, bluffs and terraces no longer confine the river. The lack of confining features and the reduced gradient cause the channel to change to sand-bedded, meandering morphology. Meanders become more sinuous as the river runs up against the prograding alluvial fans of the drainages in the Coast Ranges.

Large-scale sloughs typify the lower reaches of the San Joaquin River, beginning at the point of diversion of the Chowchilla Bifurcation Structure, which diverts most San Joaquin River flows into the flood bypass system. Several factors combined to simplify the river channel: agricultural development occurred, the high-flow regime was reduced by Friant Dam operations, project levees were constructed, and sloughs were incorporated into flood management structures (e.g., the Chowchilla Bypass system). High-flow scour channels were eliminated, the main channel’s footprint was reduced, and side channels were cut off from the river.

Along the valley floor, natural floodplain levees and floodplains were originally the major features confining the San Joaquin River channel. Before the flood bypass system and confining features such as canals and levees were developed, many large multiple-channel sloughs originated from the San Joaquin River, which probably conveyed summer and winter base flows. Today, however, human-made structures—canal embankments, San Joaquin River Flood Control Project levees, and nonproject levees—confine the river on both banks and prevent most overbank flows, channel migration, and avulsion. These channels carry mainly agricultural return flows and runoff. Downstream from the flood bypass system, the highly sinuous San Joaquin River is generally confined by project levees to its terminus in the Delta. The San Joaquin River’s flood management system is described further in Section 3.13, “Hydrology.”

Regional patterns of sediment deposition and deformation in the San Joaquin Valley have been strongly controlled by recent tectonic activity (Bartow 1991). Quaternary deposits in the San Joaquin Valley are deformed into a broad, asymmetrical trough with an axis 12–19 miles west of the current course of the San Joaquin River (Lettis and Unruh 1991). Valley subsidence is continuing at a minimum rate of 0.2 to 0.4 millimeter per year (mm/year) (0.008 to 0.016 inch per year (in/year)) (Lettis and Unruh 1991). Subsidence is caused partly by the uplift and tilting of the Sierran block to the east and the Coast Ranges to the west, although the rate of valley subsidence is higher than that of Sierran uplift. Subsidence in the San Joaquin Valley is also occurring because of aquifer compaction caused by pumping-related reduction of groundwater levels (see Section 3.11, “Groundwater Resources”). Valley subsidence may also be caused by sediment loading and compressional downwarping or thrust loading from the Coast Ranges (Lettis and Unruh 1991).

Geomorphology of the Delta The Delta is a series of channels and islands (or tracts) separated by more than 1,100 miles of levees (Ingebritsen et al. 2000). These lands historically consisted of various land types subjected to periodic flooding, and are underlain by peat beds more than 40 feet thick in some areas that accumulated over the course of the past 10,000 years (Thompson 2006). The soil was saturated with water, and organic matter accumulated faster than it could decompose.

Land in the Delta is known to be subsiding mainly because soils with high organic content are oxidizing/decomposing as a result of reclamation (removing soil saturation) and agricultural activity. Subsidence is also resulting from regional deformation controlled by tectonic activity and stress loading, as discussed above in the “Geomorphology of the San Joaquin River Watershed” section. Extraction of natural gas in the Delta may also contribute to subsidence. Elsewhere in the study area, subsidence is known to be occurring because aquifers have been compacted as pumping has reduced groundwater levels (see Section 3.11, “Groundwater Resources”).

Reclamation of Delta islands and tracts began in the late 19th century and continued into the 1930s, and agricultural production continues today on many of these lands. Levees were developed to prevent flooding and these newly protected islands, consisting primarily of tule marsh, were drained and cleared to permit agricultural development (Thompson 2006). Draining and clearing these islands frequently involved burning the drained land to remove vegetation. This process rapidly oxidized the peat bed, releasing much of the soil into the atmosphere as carbon dioxide and reducing the elevation of the land by several inches at a time. When flooding ceased, aerobic (oxygen-rich) conditions developed in the peat, which allowed for continued microbial oxidation of the carbon in the peat soil and further contributed to land subsidence (Deverel and Rojstaczer 1996).

Reclamation and ongoing agricultural production on the islands have helped cause land elevations to subside to as much as 25 feet below mean sea level in some areas. Ongoing levee maintenance and active drainage prevent most flooding but enable these islands to continue subsiding (Thompson 2006). The Delta’s flood management system is described further in Section 3.13, “Hydrology.”

Seismicity and Neotectonics

The Coast Range, Great Valley, and Sierra Nevada provinces are subject to minor tectonic activity. Fault activity is shown in Figure 3.10-2.

Both the Great Valley and Sierra Nevada provinces are part of the Sierra Nevada microplate (also referred to as the Sierran microplate), which is one component of a broad, tectonically active belt that accommodates motion between the North American plate to the east and the Pacific plate to the west. On its eastern side, the Sierra Nevada microplate is bounded by the Sierra Nevada frontal fault system, marking the beginning of the Basin and Range Province. This system, marked by the steep eastern escarpment of the Sierra Nevada, is characterized by normal and right-lateral strike-slip faults. (In a normal fault, the side of the fault lying on top of the fault moves downward, while the side beneath the fault moves upward. In a right-lateral strike-slip fault, the sides of the fault move sideways rather than up or down, with the relative motion of the right side of the fault moving toward the viewer and the left side moving away from the viewer.) To the west, the microplate is bounded by the fold and thrust belt of the Coast Range Province (Wakabayashi and Sawyer 2001).

Relative to the North American plate to the east, the right-lateral movement of the Sierra Nevada microplate is 10–14 mm/year (0.4 to 0.6 in/year). The microplate’s right-lateral motion relative to the Pacific plate to the west is much higher, at 38–40 mm/year (1.5 to 1.6 in/year). Much less deformation occurs within the Sierra Nevada microplate than along its boundaries. However, vertical deformation along the frontal fault system has caused the Sierra Nevada mountain block to tilt toward the west or southwest (Bartow 1991; Wakabayashi and Sawyer 2001). Westward tilting has been concurrent with 5,610–6,330 feet of uplift by the Sierra Nevada crest over the past 5 million years—uplift of 0.34 to 0.39 mm/year (0.013 to 0.015 in/year) (Wakabayashi and Sawyer 2001). This uplift triggered rapid stream incision and deep canyon erosion by the San Joaquin River and its tributaries, which drain the range (Wakabayashi and Sawyer 2001).

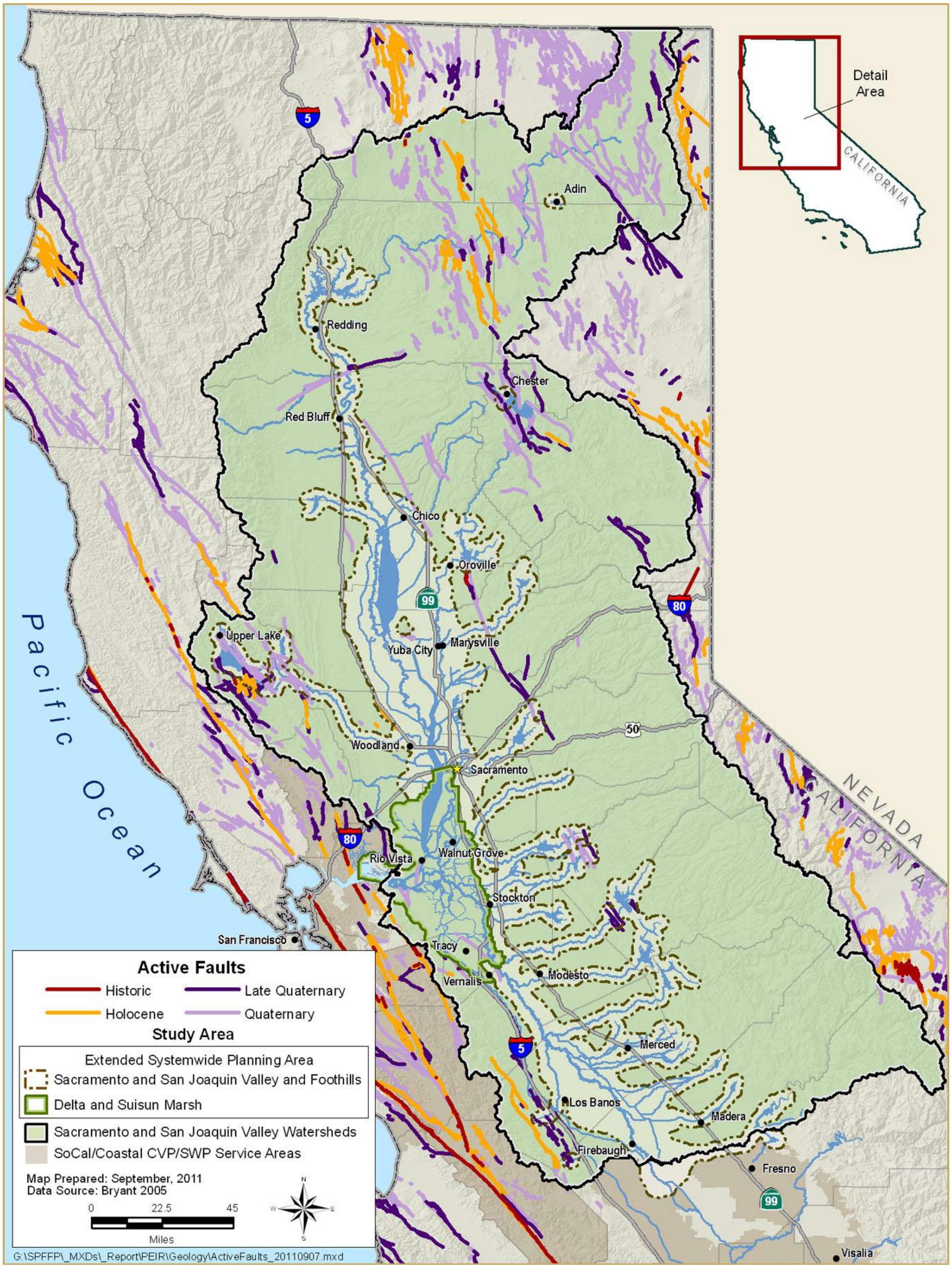

Figure 3.10-2. Fault Activity in the Study Area

The easternmost fault subsystem separating the Central Valley from the Coast Ranges is the Great Valley blind thrust, part of the San Andreas Fault system. This reverse fault separates Great Valley sequence deposits to the east from Franciscan rocks to the west. The fault subsystem consists of at least 14 segments covering an area of more than 300 miles, although precise locations of the fault's surface traces are not well documented (USGS 1996). The San Andreas fault system includes many smaller faults with varying rates of motion and seismic risk. Within the study area, the San Andreas, Calaveras, and Hayward faults are three of the most active faults in this system. The San Andreas Fault is a northwest-trending fault in the northern, central, and southern Coast Ranges. The Calaveras and Hayward faults are northwest-trending faults in the central Coast Ranges. The Great Valley thrust system is thought to accommodate 0.5 to 1.5 mm/year (0.02 to 0.06 in/year) of motion (CGS 2010b; USGS 1996).

Central Valley Ground-Shaking and Liquefaction Hazards Although a fault rupture can cause substantial damage along its narrow surface trace, earthquake damage is caused mainly by strong, sustained ground-shaking (Working Group on California Earthquake Probabilities 2003). Seismic ground-shaking can also cause soils and unconsolidated sediments to compact and settle. If soils or sediments are saturated, compaction can force pore water upward to the ground surface. This soil deformation, called liquefaction, may cause the ground to sink or pull apart or temporarily behave like a liquid instead of solid ground, causing minor to major damage to infrastructure. The potential for earthquake ground-shaking hazards is low in most of the San Joaquin Valley and Sierra Nevada foothills (CSSC 2003). The Central Valley is not considered a high-risk liquefaction area because of its generally low risk of earthquake and ground-shaking hazards; however, some liquefaction risk is assumed to exist throughout the valley where unconsolidated sediments and a high water table coincide, such as near rivers and in wetland areas (Merced County 2007).

Delta Ground-Shaking and Liquefaction Hazards Seismic activity on the Hayward, Calaveras, or San Andreas Fault presents the most probable seismic risk to levees in the Delta. The probability that these and related faults in the Delta will cause a large earthquake (magnitude 6.7 or greater) in the near future (before 2031) is shown in Figure 3.10-3.

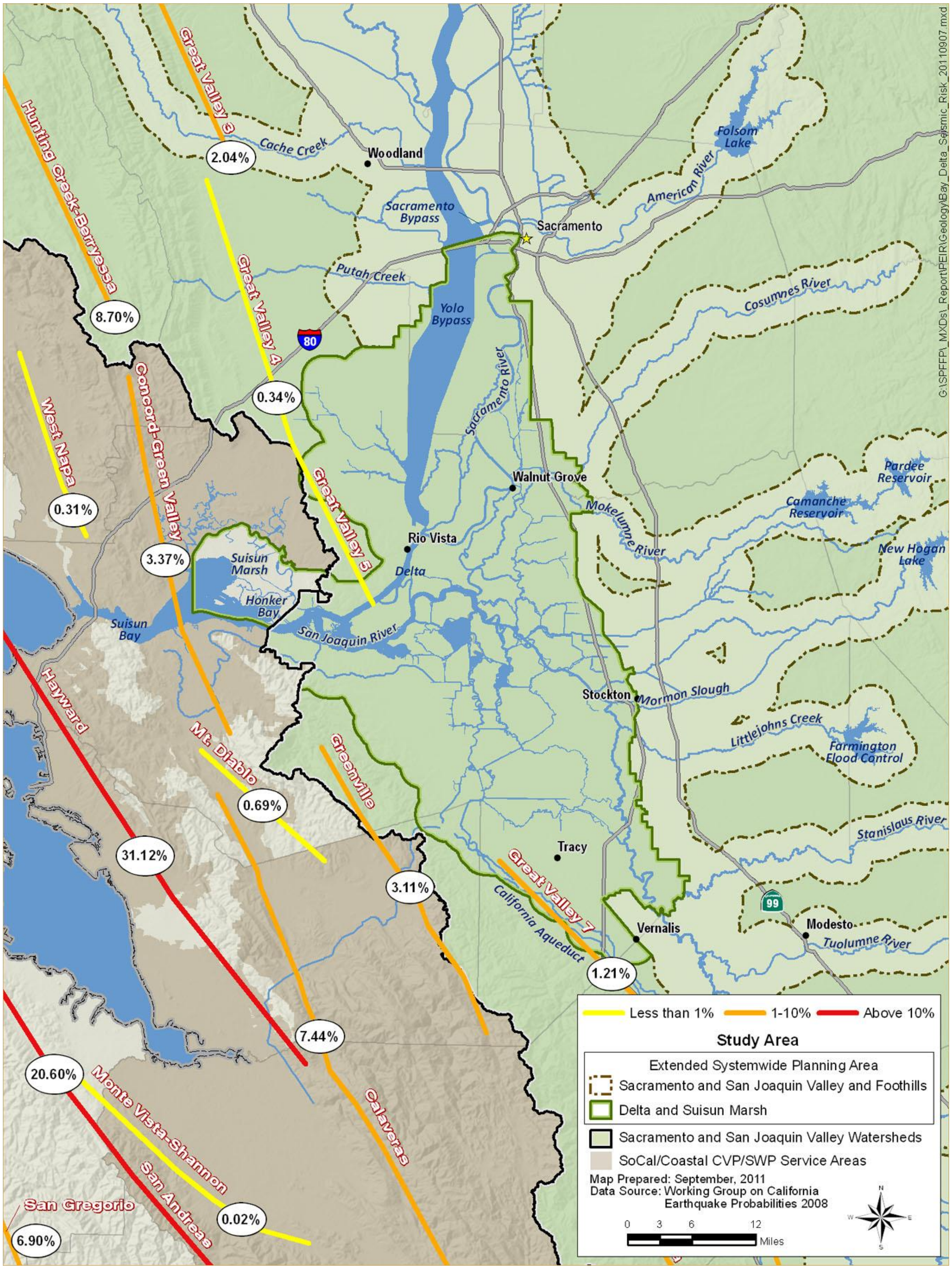

Figure 3.10-3. Faults in the Delta, with Chances of a Magnitude 6.7 or Greater Earthquake Between 2002 and 2031

Seismic risk in the Delta is related primarily to ground-shaking and associated liquefaction hazards. Delta levees built on liquefiable sediments are expected to experience large deformations (more than 10 feet) under a moderate to large earthquake in the region. At Suisun Marsh, large earthquake-induced deformations are anticipated with strong shaking because of the deep, very soft clay deposits at the levee foundations. The northern and southeastern areas of the Delta show the highest potential for liquefaction. The variable compositions and foundations of levees throughout the Delta contribute to the variable risk for individual levees and islands, while tidal influence on water elevation on the levees adds to the spatial and temporal variability of liquefaction risk in the Delta. Generally, Delta levees with liquefiable fill, or with organic soil foundations or potentially liquefiable sand deposit foundations, are at the highest risk of failure from seismic shaking. Most islands have at least one levee meeting these characteristics (DWR 2009).

Soil Types

Development of individual soils is based largely on parent material, climate, associated biology, topography, and age. These factors combine to create the more than 2,000 unique soils in California. Because soil-forming factors are similar within physiographic regions, soils in the Central Valley are described here according to four distinct physiographic regions: valley basin, valley land, terrace land, and upland. These soil types and their typical locations are summarized in Table 3.10-2.

Valley basin and valley land soils occupy most of the Central Valley floor (Figure 3.10-4). Valley basin soils consist of organic, imperfectly drained, saline, and alkali soils in the valley trough and on the basin rims. Valley land soils consist of deep alluvial and eolian soils that make up some of the best agricultural land in California. Areas above the Central Valley floor, at higher elevations and on steeper slopes, support terrace land and upland soils. Overall, these soil types are not as productive as valley land and valley basin soils. Without irrigation, these soils are used primarily for grazing and timberland; with irrigation, additional crops can be grown. These soil types and their geographic extents are described in detail in the following subsections.

Table 3.10-2. Summary of Soils in the Study Area

Physiographic Region and Soil Type	Location	Texture
Valley Basin		
Organic soils	Sacramento–San Joaquin Delta	Peat, organic
Imperfectly drained soils	Sacramento and San Joaquin Valley trough	Clays
Saline/alkaline soils	West side of the San Joaquin Valley	Clay loam–clay
Valley Land		
Alluvial soils	Alluvial fans and low terraces in the Sacramento and San Joaquin valleys	Sandy loam–loam
Aeolian soils	Portions of Stanislaus, Merced, and Fresno counties	Sands–loamy sand
Terrace Land		
Brown, neutral soils	West side of the Sacramento Valley and southeast San Joaquin Valley	Loam–clay
Red-iron hardpan soils	East side of the Sacramento and San Joaquin valleys	Sandy loam–loam hardpan
Upland		
Shallow depth to bedrock	Foothills surrounding the Central Valley	Loam–clay loams
Moderate depth to bedrock	Eastern Merced and Stanislaus counties	Sandy loam–clay loam
Deep depth to bedrock	Higher elevations of the Sierra Nevada, Klamath Mountains, and Coast Ranges	Loam—clay loams

Source: University of California 1980

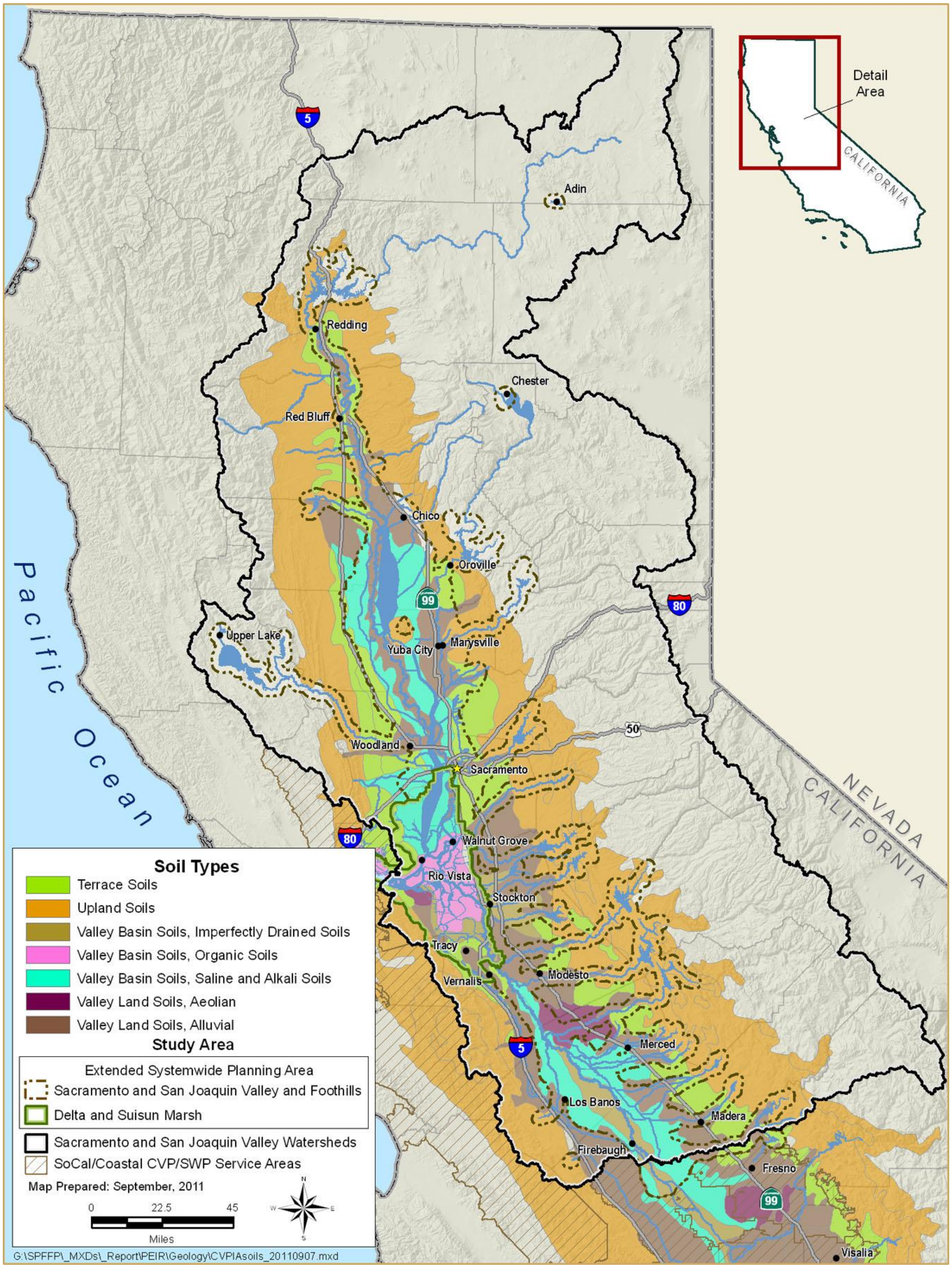

Figure 3.10-4. Soil Types in the Study Area, by Physiographic Region

Valley Basin Soils Valley basin soils occupy the lowest parts of the Central Valley and dominate Delta soils. These soils fall into three categories: organic soils, imperfectly drained soils, and saline/alkaline soils. Figure 3.10-4 shows the distribution of valley basin soils.

- **Organic soils** are so named, and are dark and acidic, because of their high organic matter content—12 percent or more by weight and typically more than 50 percent in the upper layers. Usually referred to as peat, these soils often form in areas that are frequently saturated with water (poorly drained), and are therefore common in the Delta. As described previously, these soils are prone to rapid oxidation; the development of Delta islands and tracts and the reduced inundation caused by levee construction and maintenance has led to considerable subsidence of Delta lands with this soil type.

- **Imperfectly drained soils** generally contain dark clays, and have a high water table or are subject to overflow under high-intensity precipitation events that exceed the soil's infiltration capacity. These soils are common in the troughs of the Sacramento and San Joaquin valleys, and consist in part of several thick lake-bed deposits.

- **Saline/alkaline soils** are characterized by excess salts (saline), excess sodium (sodic), or both (saline-sodic). In many of the older soil surveys, salinity and sodicity were jointly referred to as "alkaline." A distinction was sometimes made because the saline soil often formed a white crust on the surface and was called "white alkali," and the soils with excess sodium appeared to be "black"—thus, black alkali. Like imperfectly drained soils, saline/alkaline soils typically have a low infiltration capacity, and are subject to overflow under high-intensity precipitation events.

Valley Land Soils Valley land soils are generally found on flat to gently sloping surfaces, such as on alluvial fans. These well-drained and moderately well-drained soils have relatively high infiltration capacities, and include some of the best all-purpose agricultural soils in California. Both alluvial and eolian-deposited soils are present in the Central Valley. Figure 3.10-4 shows the distribution of valley land soils.

- **Alluvial soils** comprise calcic brown, noncalcic brown, and gray desert alluvial soils. Figure 3.10-4 shows the distribution of Central Valley alluvial soils. Calcic brown and noncalcic brown alluvial soils are found in the Central Valley on deep alluvial fans and floodplains in areas of intermediate rainfall (10–20 inches annually). These two soils tend to be brown to light brown with a loamy texture that forms soft clods. Calcic brown soil is calcareous (primarily composed of calcium carbonate); noncalcic soil is usually neutral or slightly acid. Gray desert alluvial soil is found on alluvial fans and floodplains in areas of low rainfall (4–7 inches annually).

- **Aeolian-deposited soils** and wind-modified soils found on the east side of the San Joaquin Valley are noncalcic brown sand soils. These soils are prone to wind erosion, have low water-holding capacity, and are somewhat deficient in plant nutrients.

Terrace Land Soils Terrace land soils are found along the edges of the Central Valley at elevations just above the valley floor. Several groups of terrace soils surround the floor of the Central Valley. Two of the more widespread groups are discussed below. Terrace land soils are grouped together and shown in Figure 3.10-4.

- **Brown, neutral soils** consist of moderately dense, brownish soils of neutral reaction. These soils are found in areas that receive 10–20 inches of rain per year. In the southeast San Joaquin Valley these soils tend to have a clay texture, while on the west side of the Sacramento Valley these soils have a loamy texture.

- **Red-iron hardpan soils** have a red-iron hardpan layer and are found along the east side of the Sacramento and San Joaquin valleys. These soils consist of reddish surface soil with a dense silica-iron cemented hardpan that is generally 1 foot thick. Some of these hardpan soils have considerable amounts of lime. These soils occur in areas that receive 7–25 inches of rain per year.

Upland Soils Upland soils are found on hilly to mountainous topography and are formed in place as the underlying parent material decomposes and disintegrates. The more widespread upland soil groups are those with shallow depth, moderate depth, and deep depth to bedrock. Two upland soil groups, shallow depth and moderate depth, are more common because of their geographic locations and elevations. Upland soils are found around the perimeter of the Central Valley (Figure 3.10-4). Soils on the west side of the valley have developed mostly on sedimentary rocks while those on the east side typically developed on igneous rocks. Upland soils are well drained or somewhat excessively drained.

- **Upland soils with shallow depth to bedrock** are found in the foothills of the Sierra Nevada and Coast Ranges that surround the Central Valley. The soils have a loam to clay-loam texture with low organic matter, and some areas have calcareous subsoils. These soils usually have a shallow depth to weathered bedrock, less than 2 feet, and are subject to overland flow. These soils are found in areas of low to moderate rainfall that support grasslands used primarily for grazing. Tilled areas are subject to considerable erosion.

- **Upland soils with moderate depth to bedrock** are found on hilly to steep upland areas of medium rainfall that can support grasslands. These soils have a sandy-loam to clay-loam texture and moderate depth to weathered bedrock, about 2 feet. This soil group is slightly acidic.

- **Upland soils with deep depth to bedrock** are found at the higher elevations in the Sierra Nevada and Coast Ranges on hilly to steep topography. These soils are characterized by moderate to strongly acidic reaction, especially in the subsoils, which can extend 3–6 feet before reaching bedrock. Bedrock consists of metasedimentary and granitic rocks. Soils forming on granitic rocks consist of decomposed granitic sands. These soils receive 35–80 inches of precipitation per year and support extensive forests.

Soil Properties and Processes Affecting Land Management

Of the thousands of soil properties and processes that lead to challenges for land management, several key properties and processes broadly affect land management: soil salinity and selenium, infiltration capacity, and soil erosion and sedimentation. Land management actions in the study area, in turn, influence each of these key properties and processes. Soil salinity and selenium, infiltration capacity, and soil erosion and sedimentation are controlled by similar properties and therefore are closely related processes. These properties and processes are summarized below; where they are characteristic of a soil type, they are identified in the subsequent discussion under “Soil Types.”

Soil Salinity and Selenium In parts of the San Joaquin Valley, the combination of a high water table, heavy irrigation practices, and the region’s geology has caused salts to accumulate in the soil. Localized clay layers contribute to a naturally high water table in these portions of the valley, concentrating salts in the root zone through evaporation. On the west side of the San Joaquin Valley, many of the saline/alkaline soils (discussed previously and shown in Figure 3.10-4) are irrigated with moderately saline Delta surface water, imported via the Delta-Mendota Canal and the California Aqueduct, or with slightly to moderately saline groundwater (this combination of factors is unique to this portion of the study area). Salts are added when fertilizers or other additives needed for cropping are applied. Farmers actively leach these salts through irrigation and subsurface drainage. Drainage water with high concentrations of salts may accumulate in groundwater, or may be discharged to evaporation ponds or the San Joaquin River. To minimize salinity problems, irrigators apply water to the soil before planting seed or plants to leach salts from the root zone.

Because of the rise in groundwater salinity, the portion of the study area with soil salinity problems has grown. Soil salinity increased most recently during the drought of 1987–1992, when the availability of surface water was limited and groundwater use escalated. Leaching also increases the salinity in flows from subsurface drains, which affects the water quality of surface waters that receive return flows, or the quality of water and sediments in evaporation ponds. The U.S. Department of the Interior, Bureau of Reclamation (Reclamation) and San Luis Delta-Mendota Water Authority are working together to address this issue in part through the Grassland Bypass Project (Reclamation 2010).

Naturally occurring salts, such as selenium, can pose a hazard to fish and wildlife when discharged to surface waters in high concentrations. Although soils throughout the San Joaquin Valley typically contain some selenium, soils on the valley’s west side are particularly enriched in selenium. These soils have developed on the alluvial deposits that carry sediments out of the Coast Ranges, where selenium is concentrated in marine deposits (SJDVP 1990).

Infiltration Capacity Soil infiltration capacity, or the maximum rate at which soils can absorb rainfall and transmit it to the subsurface, depends on multiple interrelated factors: initial moisture content, texture, structure, and uniformity or layering of the soil profile. Fine soils, particularly soils with high clay content, have a lower initial infiltration capacity than coarser, sandy soils. As soil moisture increases, such as during a precipitation event, the infiltration rate also decreases more rapidly in finer soils (Hillel 1998).

Overland flow occurs when rainfall rates exceed the infiltration rate; such flow contributes to erosion (described below). Similarly, infiltration on floodplains contributes to the recession of floodwater. The relationship of soil texture to infiltration capacity can be used to understand the relative distribution of infiltration capacity (Table 3.10-2 and Figure 3.10-4). As shown in Table 3.10-2 and Figure 3.10-4, clay-rich soils are common throughout the Sacramento and San Joaquin valleys, particularly along the main rivers and on floodplains. These soils tend to have low to moderate infiltration capacities. Alluvial and eolian soils are also common, and tend to have higher infiltration capacities because of their higher sand content. However, localized conditions such as agricultural practices, forest fires, salinity, and vegetation strongly affect infiltration capacities. Flooding tends to contribute fine sediments such as clay particles to floodplains, contributing to lower infiltration capacities on floodplain soils (Ghazavi et al. 2010).

Fine-textured soils are common throughout floodplains and basins of the Sacramento and San Joaquin valleys, and have very slow or moderately slow infiltration rates. However, stream-channel deposits of coarse sands are present along the Sacramento and San Joaquin rivers and their major tributaries, and are characterized by relatively high infiltration rates (Domagalski et al. 2001).

Soil Erosion and Sedimentation Soil surface texture and structure, particle size, permeability, infiltration rate, and the presence of organic or other cementing materials all affect the potential for erosion. Other key factors determining erosion potential are the extent of vegetation, type of vegetative cover, human or other disturbance, topography, and rainfall. In general, soils on steep, unvegetated slopes—especially slopes greater than 30 percent—are particularly vulnerable to erosion. Because natural and cut slopes in decomposed granite soils erode readily, soil in the Sierra Nevada and foothills is particularly vulnerable to erosion (FERC 2002). Human activities such as construction and development (which usually involve removing vegetation, compacting porous soils, and draining large areas) can also effectively accelerate natural erosion processes.

Mineral Resources

Mineral resources in California include nonfuel mineral resources, such as metals and aggregates, and oil and gas resources. Mineral resources in California are described below.

Nonfuel Mineral Resources In 2008, California ranked fifth in the nation in nonfuel mineral production. In that year, California yielded $4.0 billion in nonfuel minerals, totaling 5.6 percent of the nation’s entire production (Kohler 2009). The value and quantity of the most economically important nonfuel mineral products produced in the state are summarized in Table 3.10-3. Most current gold production in California occurs outside the study area; aggregate mining, described below, is the most prevalent mineral production that occurs within the study area. As described previously, historic hydraulic and placer gold mining operations considerably altered fluvial geomorphology throughout the Sacramento and San Joaquin Valley watersheds.

Table 3.10-3. California Nonfuel Mineral Production, 2008

Product	Quantity[a]	Value ($ thousands)
Boron Minerals	C	700,000[a,b]
Cement		
Masonry	377,000[b] tons	46,000[a]
Portland	10,496,000[b] short tons	1,091,000[a]
Clays		
Bentonite	33,000 short tons	3,200
Common	515,000 short tons	3,400
Gemstones	NA	700
Gold[c]	119,300[c] troy ounces[d]	104,100[b]
Sand and Gravel		
Construction	108,529,000 short tons	1,105,100
Industrial	1,940,000 short tons	42,900
Silver[c]	3,590 troy ounces	50
Stone		
Crushed	48,196,000 short tons	480,300
Dimension	47,000 short tons	12,200
Total Combined Values of Other Minerals[e,f]	NA	393,300
Total	NA	3,978,800

Source: Kohler 2009

Notes:

[a] Production quantity as measured by mine shipments, sales, or marketable production (including consumption by producers). Quantity and value data are rounded to the nearest 100 units, except for silver (rounded to nearest 10 units). Values are preliminary and subject to change.

[b] Estimated value.

[c] Data from California Geological Survey.

[d] Troy ounce = 1.0971 “standard” ounces

[e] Recoverable content of ores, etc.

[f] Values for other clays (fire, fullers earth, and kaolin), diatomite, feldspar, gypsum, iron ore, lime, magnesium compounds, perlite, pumice and pumicite, rare earths, salt, soda ash, silver, sodium sulfate, and zeolites.

Key:

C = Withheld to avoid disclosing company proprietary data; value included with "total combined" data

NA = Not available

Aggregate mining occurs within many streams in the western foothills of California. Generally, these rivers or streams are located along natural troughs of gravel and sand deposits. Aggregate mining also occurs along the coastal streams and in the coastal dunes. Unconsolidated gravels and slates also are mined in the lower foothills of the Sierra Nevada. Because of the proximity of these deposits to the ground surface, and because they are located on flat land, these deposits have been mined for many years. Within the Extended SPA, large aggregate production areas (those producing 500,000 million tons or more in 2005) are located on most major waterways, typically upstream of SPFC levees. Several small aggregate production areas (producing less than 500,000 million tons in 2005) are located between or near SPFC levees along the Sacramento and Feather rivers (Kohler 2006).

Aggregate is used primarily for building and road materials. The 50-year demand (January 2006 through December 2055) for aggregate in California is estimated to exceed the permitted aggregate resources within the state (Table 3.10-4).

Table 3.10-4. Comparison of 50-Year Demand to Permitted Aggregate Resources for Aggregate Study Areas as of January 1, 2006

Aggregate Study Area[1,2]	**50-Year Demand (million tons)**	**Permitted Aggregate Resources (million tons)**	**Permitted Aggregate Resources Volume as Percentage of 50-Year Demand**
Bakersfield P-C Region	252	115	46
Barstow-Victorville P-C Region	179	133	74
Claremont-Upland P-C Region	300	147	49
El Dorado County	91	19	21
Fresno P-C Region	629	71	11
Glenn County	83	17	21
Merced County[3]			
Eastern Merced County	106	53	50
Western Merced County	53	Proprietary	<50
Monterey Bay P-C Region	383	347	91
Nevada County	122	31	25
Palmdale P-C Region	665	181	27
Palm Springs P-C Region	295	176	60
Placer County	171	45	26
North San Francisco Bay P-C Region	647	49	8
Sacramento County	733	67	9
Sacramento-Fairfield P-C Region	235	164	70
San Bernardino P-C Region	1,074	262	24
San Fernando Valley–Saugus–Newhall[2]	457	88	19
San Gabriel Valley P-C Region	1,148	370	32
San Luis Obispo–Santa Barbara P-C Region	243	77	32
Shasta County	122	51	42
South San Francisco Bay P-C Region	1,244	458	37

Table 3.10-4. Comparison of 50-Year Demand to Permitted Aggregate Resources for Aggregate Study Areas as of January 1, 2006 (contd.)

Aggregate Study Area[1,2]	50-Year Demand (million tons)	Permitted Aggregate Resources (million tons)	Percentage of Permitted Aggregate Resources as Compared to the 50-Year Demand
Stanislaus County	344	51	15
Stockton-Lodi P-C Region	728	196	27
Tehama County	72	36	49
Temescal Valley–Orange County[2]	1,122	355	32
Tulare County[3]			
Northern Tulare County	117	12	10
Southern Tulare County	88	Proprietary	<50
Ventura County[3]	309	106	34
Western San Diego County P-C Region	1,164	198	17
Yuba City–Marysville P-C Region	360	409	>100
Total	**13,536**	**4,343**	32

Notes:
[1] Aggregate study areas follow either the boundary of a Production-Consumption (P-C) region or a county boundary. A P-C region includes one or more aggregate production districts and the market area that those districts serve. Aggregate resources are evaluated within the boundaries of the P-C region. County studies evaluate all aggregate resources within the county boundary.
[2] Study areas with less than 10 years of permitted resources are in **bold type**.
[2] The county study has been divided into two areas, each having its own production and market area. A separate permitted resource calculation and 50-year forecast is made for each area.
[3] Two P-C regions have been combined into one study area.
Key:
P-C = Production-Consumption

Instream gravel mining causes substantial water quality and habitat problems because sediments in the river increase and soils with nutrients and vegetation are removed in the area of the mining activities. Increased sedimentation may affect both the tributary stream where the aggregate mining occurs and the main stream reach. Exposure of soils and minerals to water can leach chemicals from those sediments, potentially causing toxicity problems in receiving waters. Sedimentation can adversely affect survival of fish in streams by increasing stream turbidity; increasing sedimentation of spawning gravels, which reduces intergravel flow; potentially reducing levels of dissolved oxygen; and increasing the potential for algal growths because of the reduction in light penetration through the water column. Instream gravel mining can also remove spawning gravel and habitat. Finally, instream gravel mining creates multiple channels along or adjacent to the streambed. Many of the channels may be considered “dead-ends” or may end in shallow pools characterized by high temperatures or high sediments. This “braiding” of channels can cause navigation problems or entrainment of fish. Conversely, instream gravel mining produces channels and pits that, in some cases, may attenuate flood flows, reducing flood peaks.

Oil, Gas, and Geothermal Resources California's oil and gas resources are found in 29 counties. California's rate of oil and gas production fell slightly in 2008, averaging about 651,900 barrels of crude oil per day, 205.5 billion cubic feet of gas that is associated with oil (associated gas), and 91.5 billion cubic feet of gas that is unassociated with oil (unassociated gas). Despite decreased production, California ranked fourth among oil-producing states in 2008 (DOGGR 2009).

Gas fields are located throughout the study area, but are particularly prevalent throughout the Sacramento Valley and the Delta. Conversely, oil fields are largely confined to the southern San Joaquin Valley and the Central Valley Project (CVP) and State Water Project (SWP) water service areas in Southern California. (A few small oil fields are located within the Delta.) The five largest-producing oil fields in California in 2008 are all located in the southern San Joaquin Valley; the Midway-Sunset, South Belridge, Kern River, Cymric, and Elk Hills oil fields produced 36.3, 32.5, 29.5, 18.0, and 14.9 million barrels, respectively. California is also an important producer of energy from geothermal resources, but no active geothermal production fields are located within the study area (DOGGR 2001, 2009).

Paleontological Resources

In its standard guidelines for assessment and mitigation of adverse impacts on paleontological resources, the Society of Vertebrate Paleontology (SVP) (1995) established three categories of sensitivity for paleontological resources: high, low, and undetermined. Areas where fossils have been found previously are considered to have high sensitivity and high potential to produce fossils. Areas that are not sedimentary in origin and that have not been known to produce fossils in the past typically are considered to have low sensitivity. Areas without any previous paleontological resource surveys or fossil finds are considered to be of undetermined sensitivity until surveys and mapping are performed to determine their sensitivity. After reconnaissance surveys, observation of exposed cuts, and possibly subsurface testing, a qualified paleontologist can determine whether an area should be categorized as having high or low sensitivity. In keeping with the significance criteria of the SVP (1995), all vertebrate fossils are generally categorized as being of potentially significant scientific value.

Given the size of the study area and variation in potential physical construction activities with potential to affect paleontological resources of varying sensitivity, a detailed description of potentially significant paleontological resources within the study area is beyond the scope of this program-level discussion. Therefore, the following descriptions of the conditions present in California throughout geologic history are provided to indicate the geologic setting under which paleontological resources may be identified during project-specific research associated with environmental compliance documentation. Figure 3.10-5 shows the approximate eras associated with rock formations in California.

Precambrian Era—Approximately 4.5 Billion to 540 Million Years Ago Within the study area, sedimentary rocks from the Precambrian and Early Paleozoic are most often found in SWP service areas in Southern California. Most rocks of Precambrian age do not contain fossils, although some traces and a few fossils have been found dating to the Proterozoic Eon (between approximately 2.5 billion and 540 million years ago).

Paleozoic Era—540 Million to 250 Million Years Ago Deposits from the mid to late Paleozoic (Cambrian through Devonian periods) are common in the Klamath Mountains and Sierra Nevada provinces. These deposits may contain numerous marine fossils, including corals, ammonites, and brachiopods. Freshwater and marine sedimentary rocks deposited in the late Paleozoic exhibit fossils from both shallow- and deep-water deposits, including swamps and estuarine deposits. These formations are found primarily in the northern portion of the study area (Shasta and Butte counties).

Mesozoic Era—250 Million to 65.5 Million Years Ago Uplifting of the Sierra Nevada Province during the Mesozoic Era led to erosion of the mountain range and deposition in the Great Valley Province during this era. Invertebrates, marine reptiles, and a variety of terrestrial flora are represented in the fossil record in Mesozoic rocks throughout California. Uplift of the Coast and Transverse ranges also began in the latter part of the Mesozoic.

Cenozoic Era—65.5 Million Years Ago to Present Continuing uplift of the Coast and Transverse ranges, fluctuating sea levels, glaciations in the Sierra Nevada, and development of today’s lakes and river systems led to deposition of shallow marine, estuarine, freshwater, and terrestrial rocks throughout California. Cenozoic fossil records in these rocks are diverse and include marine, freshwater, and terrestrial flora and fauna. The Pleistocene epoch, known as the “great ice age,” began during the Cenozoic approximately 1.8 million years ago. Mammalian inhabitants of the Pleistocene alluvial fan and floodplain included mammoths, mastodons, horses, camels, ground sloths, and pronghorn antelopes.

Fossilization is a lengthy and gradual process. Completion of the process depends on various factors, such as pH, temperature, and mineral composition. By definition, a remain must be preserved from a past geologic age to be considered a true fossil. Because the Holocene age comprises the past 11,000 years to the present day, it is considered the modern era/current geologic age, and, therefore remains dated during the past 11,000 years are not considered fossils. Formations in areas with recent or ongoing geologic processes are more likely to contain deposits from the Holocene age, and would not be anticipated to contain fossils. Many deposits of the Holocene age are likely to be found in or near waterways: younger aged alluvial deposits, natural levee and channel deposits, basin deposits, peat and mud (including tidal deposits), dredge and mine tailings, and artificial fill. For example, on the valley floor, along much of their length, the Sacramento and San Joaquin rivers traverse Holocene deposits within the bounds of their levees (natural or constructed); however, in the foothills and mountains, these rivers and their tributaries encounter deposits from the Pleistocene or earlier. Conversely, conditions in ideal locations for dams and reservoirs are often associated with older, more consolidated formations.

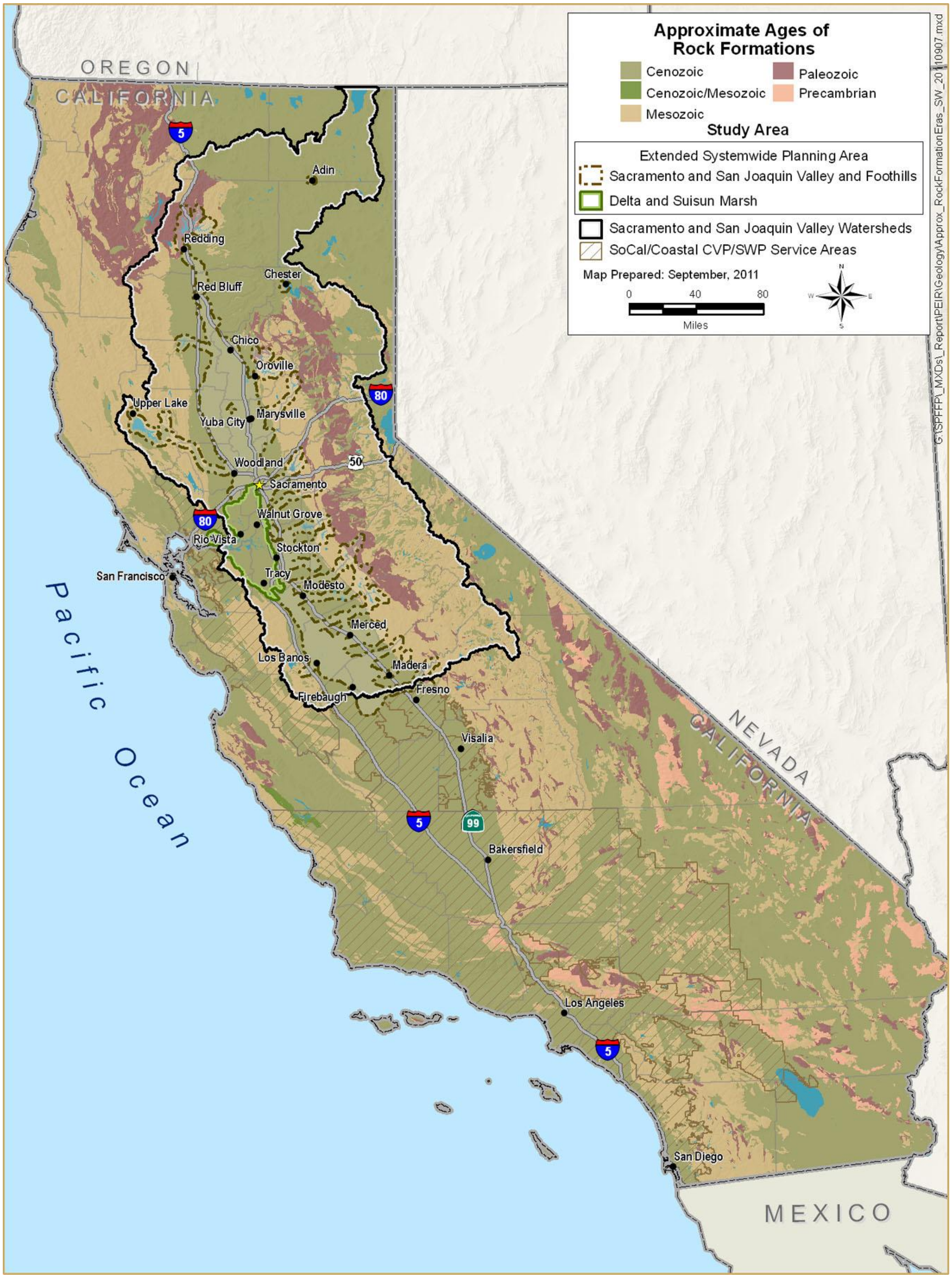

Figure 3.10-5. Approximate Eras Associated with Rock Formations in California

3.10.2 Regulatory Setting

The following text summarizes federal, State, and regional and local laws and regulations pertinent to evaluation of the proposed program's impacts on geology, soils, and seismicity (including mineral and paleontological resources).

Federal

Antiquities Act of 1906 As discussed in Section 3.8, "Cultural and Historic Resources," the Antiquities Act of 1906 (Public Law 59-209; 16 U.S. Code (USC) 431 et seq.; 34 Stat. 225) requires protection of historic landmarks, historic and prehistoric structures, and other objects of historic or scientific interest on federal lands. Paleontological resources are included in this category by many federal agencies such as the U.S. Bureau of Land Management. In addition, the National Environmental Policy Act (NEPA), as amended, requires federal agencies to consider the impact of their actions (including the issuance of entitlements or permits, or financial support, to a project) on important historic, cultural, and natural aspects of our national heritage.

Omnibus Public Land Management Act of 2009 On March 30, 2009, President Barack Obama signed into law (as Public Law 111-11) House Bill 146, the Omnibus Public Land Management Act of 2009 (OPLMA). Title 6, Subtitle D (Paleontological Resources Preservation) of the OPLMA requires the Secretaries of the Interior (exclusive of Indian trust lands) and Agriculture (insofar as U.S. Forest System lands are concerned) to "…manage and protect paleontological resources on Federal land using scientific principles and expertise… [and] develop appropriate plans for inventory, monitoring, and the scientific and educational use of paleontological resources …" The OPLMA further excludes casual collection from restrictions under the law. The act then describes the requirements for permitting collection on federal lands, stipulations regarding the use of paleontological resources in education, continued federal ownership of recovered paleontological resources, and standards for acceptable repositories of collected specimens and associated data (Sections 6303–6305). The OPLMA also provides for criminal and civil penalties for unauthorized removal of paleontological resources from federal land, and for rewards for reporting the theft of fossils (Sections 6306–6309).

CALFED Bay-Delta Program See discussion in Subsection 3.5.2, "Regulatory Setting," in Section 3.5, "Biological Resources—Aquatic."

Clean Water Act Section 402 See discussion in Subsection 3.5.2, "Regulatory Setting," in Section 3.5, "Biological Resources—Aquatic."

Federal and Other National Regulatory Design Codes for Levees and Other Structures The following federal and other national standards for minimum design regulate the construction of levees, concrete and steel structures, tunnels, pipelines, buildings, pumping stations, excavation and shoring, grading, foundations, and other structures:

- American Society of Civil Engineers, *Minimum Design Loads for Buildings and Other Structures,* ASCE-7-05, 2005
- U.S. Army Corps of Engineers (USACE), *Geotechnical Levee Practice,* SOP EDG-03, 2004
- USACE, *Design and Construction of Levees*, EM 1110-2-1913, 2000
- USACE, *Engineering and Design, Earthquake Design and Evaluation for Civil Works Projects*, ER 1110-2-1806, 1995
- USACE, *Engineering and Design—Earthquake Design and Evaluation of Concrete Hydraulic Structures,* EM 1110-2-6053, 2007
- USACE, *Engineering and Design—General Design and Construction Considerations for Earth and Rock-Fill Dams,* EM 1110-2-2300, 2004
- USACE, *Engineering and Design—Response Spectra and Seismic Analysis for Concrete Hydraulic Structures*, EM 1110-2-6050,1999
- USACE, *Engineering and Design—Stability Analysis of Concrete Structures*, EM 1110-2-2100, 2005
- USACE, *Engineering and Design—Structural Design and Evaluation of Outlet Works*, EM 1110-2-2400, 2003
- USACE, *Engineering and Design—Time-History Dynamic Analysis of Concrete Hydraulic Structure*, EM 1110-2-6051, 2003
- USACE, *Slope Stability*, EM 1110-2-1902, 2003
- U.S. Department of the Interior and U.S. Geological Survey, *Climate Change and Water Resources Management: A Federal Perspective,* Circular 1331

State

Alquist-Priolo Earthquake Fault Zoning Act California's Alquist-Priolo Earthquake Fault Zoning Act (Public Resources Code, Section 2621 et seq.), originally enacted in 1972 as the Alquist-Priolo Special Studies Zone Act and renamed in 1994, is intended to reduce the risk to life and property from surface fault rupture during earthquakes. The Alquist-Priolo Act prohibits locating most types of structures intended for human occupancy across the traces of active faults, and strictly regulates construction in the corridors along active faults (earthquake fault zones). For the purpose of this act, a fault is considered active if it displays evidence of surface displacement during Holocene time (approximately during the last 11,000 years).

Liquefaction and Landslide Hazard Maps (Seismic Hazards Mapping Act) The Seismic Hazards Mapping Act of 1990 (Public Resources Code, Sections 2690 through 2699.6) was passed after the Loma Prieta earthquake occurred, to reduce threats to public health and safety by identifying and mapping known seismic hazard zones in California. The act directs the California Geological Survey to identify and map areas prone to hazards from liquefaction, earthquake-induced landslides, and amplified ground shaking. The purpose of the maps is to assist cities and counties in fulfilling their responsibilities for protecting public health and safety. A development permit review is required for sites in the mapped seismic hazard zones. Site-specific geologic investigations and evaluations are carried out to identify the extent of hazards, and appropriate mitigation measures are incorporated in the development plans to reduce potential damage.

State Regulatory Design Codes for Levees and Other Structures The following State standards for minimum design regulate the construction of levees, concrete and steel structures, tunnels, pipelines, buildings, pumping stations, excavation and shoring, grading, and foundations, and other structures:

- California Building Code, 2007 (Title 24 of the California Code of Regulations)

- DWR, *Guidelines for Use of the Consequence-Hazard Matrix and Selection of Ground Motion Parameters*, 2002

- DWR, *Interim Levee Design Criteria for Urban and Urbanizing Area State-Federal Project Levees*, 2011

Surface Mining and Reclamation Act In 1975, the Surface Mining and Reclamation Act (SMARA) (Public Resources Code, Sections 2710 through 2796.5) mandated that the State Geologist make an inventory, by county, of mineral resources of statewide and regional significance. The purpose of SMARA is to provide a comprehensive policy on surface mining and reclamation for regulating surface mining operations to assure that adverse environmental impacts are minimized and mined lands are reclaimed to a usable condition.

SMARA regulates surface mining in California, including the use of borrow pits. SMARA does not apply to mining operations conducted by DWR for flood management on lands owned or leased by DWR, or upon which easements or rights-of-way have been obtained, if DWR adopts a reclamation plan for these lands after consultation with the California Department of Conservation (Public Resources Code, Section 2714(i)(1)).

Porter-Cologne Water Quality Control Act See discussion in Subsection 3.5.2, “Regulatory Setting,” in Section 3.5, “Biological Resources—Aquatic.”

General Permit for Stormwater Discharges from Construction Sites The State Water Resources Control Board (SWRCB) regulates stormwater discharges from projects that disturb 1 or more acres of soil, or that disturb less than 1 acre but are part of a larger common plan of development that disturbs a total of 1 or more acres. Projects that meet these conditions require coverage under the General Permit for Discharges of Storm Water Associated with Construction Activity, consistent with SWRCB Order 2009-0009-DWQ. This general permit requires the project proponent to develop and implement a storm water pollution prevention plan (SWPPP) listing the best management practices (BMPs) that the discharger will use to protect stormwater runoff and the placement of those BMPs. A sediment monitoring plan must also be prepared and implemented if the site discharges directly to a water body listed on the Clean Water Act Section 303(d) list for sediment (see also Section 3.21, “Water Quality,” for further discussion of Clean Water Act Section 303(d)).

McAteer-Petris Act The McAteer-Petris Act (California Government Code, Sections 66600–66694) is the California law that established the San Francisco Bay Conservation and Development Commission (BCDC) as a State agency. This law prescribes BCDC’s powers, responsibilities, and structure and describes the broad policies that BCDC must use to determine whether permits can be issued for activities in and along the shoreline of San Francisco Bay.

Sacramento River Management Plan In 1989, the California Legislature passed Senate Bill (SB) 1086, which called for a Sacramento River management plan to protect, restore, and enhance fisheries and riparian habitat. Implementing such a plan would create a contiguous riparian ecosystem along the upper Sacramento River between the Feather River and Keswick Dam. The plan was guided by several "themes" or goals, useful in evaluating program success:

- Management of riparian ecosystems should be accomplished from an ecosystem perspective, providing for listed species recovery while recognizing human-imposed constraints.
- Private landowners should play an active role in riparian habitat management.
- Local impacts, such as tax base reduction and public access to riparian zones, should be minimized and managed.
- When and where bank stabilization is deemed necessary, it should be accomplished using the least environmentally damaging methods possible.
- Natural revegetation should be permitted in the floodplain, but valley oak woodland should be actively restored on terraces.
- An information and education clearinghouse is needed to help riparian landowners obtain grants and technical assistance.

The *Sacramento River Conservation Area Forum Handbook* describes the implementation of SB 1086, including organizational interactions, land acquisitions, and land management along the Sacramento River between Keswick and Verona. It describes the biophysical setting of the riparian zone and includes several proposed research and monitoring actions: developing a geographic information system (GIS) model to prioritize habitats for protection, investigating succession and geomorphic processes, mapping topography, and monitoring the structure and composition of vegetation. It describes each subreach of the riparian zone and the strategies and actions that can be employed for restoration.

Suisun Marsh Preservation Act of 1977 The Suisun Marsh Preservation Act was enacted in 1977 (Public Resources Code, Section 29000 et seq.) to incorporate the findings and policies contained in the *Suisun Marsh Protection Plan* prepared by BCDC and the California Department of Fish and Game (DFG) in 1976. The Suisun Marsh Preservation Act, *Suisun Marsh Protection Plan*, and related local protection programs require that existing land and water uses continue to be protected and managed to enhance the quality and diversity of aquatic and wildlife habitat. Activities that may require a permit from BCDC include dredging, reduction of agricultural land by flooding of islands, and soil erosion controls.

In 1987, the *Suisun Marsh Preservation Agreement* (SMPA) was signed by DWR, DFG, Reclamation, and the Suisun Resource Conservation District. The purpose of the SMPA was to mitigate impacts of CVP and SWP operations and other upstream diversions on salinity in Suisun Marsh. In 2005, the Revised SMPA was signed to make channel-water salinity requirements consistent with SWRCB Decision 1641 (Reclamation et al. 2005). SWRCB Decision 1641 relieved DWR and Reclamation of the responsibility to meet salinity objectives at two control stations in the western Suisun Marsh and allowed variability in meeting the objectives.

Regional and Local

Bay Delta Conservation Plan See discussion in Subsection 3.5.2, “Regulatory Setting,” in Section 3.5, “Biological Resources—Aquatic.”

Cosumnes River Preserve Management Plan The Cosumnes River Preserve is managed by the Cosumnes River Preserve Partners, which includes the U.S. Bureau of Land Management. Any program activities that could affect resources on the preserve would need to comply with applicable requirements of this land management plan.

County and City General Plans Most counties and many cities in the study area have developed their own general plans, ordinances, policies, or other regulatory mechanisms pertaining to geology, soils, and seismicity (including mineral and paleontological resources). Typically, these regulatory mechanisms incorporate provisions of SMARA that protect significant mineral resources from incompatible land uses and regulate mining operations and reclamation. Most county and city plans have no provisions for preserving paleontological resources; however, as plans are updated, the updates often include oversight of paleontological resources in response to increased public awareness of the value of those resources.

Should a place-based project be defined and pursued as part of the proposed program, and should the CEQA lead agency be subject to the authority of local jurisdictions, the applicable county and city policies and ordinances would be addressed in a project-level CEQA document, as necessary.

San Joaquin River Parkway Master Plan See discussion in Subsection 3.5.2, “Regulatory Setting,” in Section 3.5, “Biological Resources—Aquatic.”

3.10.3 Analysis Methodology and Thresholds of Significance

This section provides a program-level evaluation of the direct and indirect effects on geology, soils, and seismicity (including mineral and paleontological resources) of implementing management actions included in the proposed program. These proposed management actions are expressed as NTMAs and LTMAs. The methods used to assess how different categories of NTMAs and LTMAs could affect geology, soils, and seismicity (including mineral and paleontological resources) are summarized in "Analysis Methodology"; thresholds for evaluating the significance of potential impacts are listed in "Thresholds of Significance." Potential effects related to each significance threshold are discussed in Section 3.10.4, "Environmental Impacts and Mitigation Measures for NTMAs," and Section 3.10.5, "Environmental Impacts, Mitigation Measures, and Mitigation Strategies for LTMAs."

Analysis Methodology

Impact evaluations were based on a review of the management actions proposed under the CVFPP, expressed as NTMAs and LTMAs in this PEIR, to determine whether these actions could potentially result in impacts on geology, soils, and seismicity (including mineral and paleontological resources). NTMAs and LTMAs are described in more detail in Section 2.4, "Proposed Management Activities." The overall approach to analyzing the impacts of NTMAs and LTMAs and providing mitigation is described in detail in Section 3.1, "Approach to Environmental Analysis." NTMAs can consist of any of the following types of activities:

- Improvement, remediation, repair, reconstruction, and operation and maintenance of existing facilities
- Construction, operation, and maintenance of small setback levees
- Purchase of easements and/or other interests in land
- Operational criteria changes to existing reservoirs that stay within existing storage allocations
- Implementation of the vegetation management strategy included in the CVFPP
- Initiation of conservation elements included in the proposed program
- Implementation of various changes to DWR and Statewide policies that could result in alteration of the physical environment

All other types of CVFPP activities fall within the LTMA category and are also described in Section 2.4. NTMAs are evaluated using a typical "impact/mitigation" approach. Where impact descriptions and mitigation measures identified for NTMAs also apply to LTMAs, they are also attributed to LTMAs, with modifications or expansions as needed.

Thresholds of Significance

For the purpose of this analysis, the following applicable thresholds of significance have been used to determine whether implementing the proposed program would result in a significant impact. These thresholds of significance are based on Appendix G of the CEQA Guidelines, as amended. An impact on geology, soils, and seismicity (including mineral and paleontological resources) is considered significant if implementation of the proposed program would do any of the following when compared against existing conditions:

- Expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death, through the following:
  - Rupture of a known earthquake fault, as delineated on the most recent Alquist-Priolo Earthquake Fault Zoning Map issued by the State Geologist for the area or based on other substantial evidence of a known fault; refer to Division of Mines and Geology Special Publication 42
  - Strong seismic ground shaking
  - Seismic-related ground failure, including liquefaction
  - Landslides
- Result in substantial soil erosion or the loss of topsoil
- Be located on a geologic unit or soil that is unstable, or that would become unstable as a result of the project, and potentially result in on- or off-site landslide, lateral spreading, subsidence, liquefaction, or collapse, and these risks cannot be sufficiently reduced through engineering solutions or other means
- Be located on expansive soil, as defined in Table 18-1-B of the Uniform Building Code (1994), creating substantial risks to life or property, and this risk cannot be sufficiently reduced through engineering solutions or other means

- Have soils incapable of adequately supporting the use of septic tanks or alternative wastewater disposal systems where sewers are not available for disposal of wastewater

- Result in the loss of availability of a locally important mineral resource that would be of value to the region and the residents of the state

- Result in the loss of availability of a locally important mineral resource recovery site delineated on a local general plan, specific plan, or other land use plan

- Directly or indirectly destroy a unique paleontological resource or site or unique geologic feature

In addition, the following thresholds of significance are used to assess paleontological resources impacts. An individual vertebrate fossil specimen may be considered unique or significant if it is identifiable and well preserved and it meets one of the following criteria:

- A type specimen (i.e., the individual from which a species or subspecies has been described)

- A member of a rare species

- A species that is part of a diverse assemblage (i.e., a site where more than one fossil has been discovered) wherein other species are also identifiable, and important information regarding life history of individuals can be drawn

- A skeletal element different from, or a specimen more complete than, those now available for its species

- A complete specimen (i.e., all or substantially all of the entire skeleton is present)

For example, identifiable vertebrate marine and terrestrial fossils are generally considered scientifically important because they are relatively rare. The value or importance of different fossil groups varies, depending on the age and depositional environment of the rock unit that contains the fossils, their rarity, the extent to which they have already been identified and documented, and the ability to recover similar materials under more controlled conditions, such as part of a research project. Marine invertebrate fossil specimens are generally common, well developed, and well documented. They would generally not be considered a unique paleontological resource.

Significance Thresholds Not Evaluated Further

Unique geologic features would generally consist of sand dunes, deep river gorges, large waterfalls, unusual rock formations, prominent cinder cones or volcanoes, and similar unique formations in the landscape. In general, these would also be considered rare or exceptional scenic features. The actions contemplated under the CVFPP would be highly unlikely to intersect and adversely affect unique geologic features; therefore, this issue is not discussed further in this EIR.

3.10.4 Environmental Impacts and Mitigation Measures for NTMAs

This section describes the physical effects of NTMAs on geology, soils, and seismicity (including mineral and paleontological resources). For each impact discussion, the environmental effect is determined to be either less than significant, significant, potentially significant, or beneficial compared to existing conditions and relative to the thresholds of significance described above. These significance categories are described in more detail in Section 3.1, “Approach to Environmental Analysis.” Feasible mitigation measures are identified to address any significant or potentially significant impacts. Actual implementation, monitoring, and reporting of the PEIR mitigation measures would be the responsibility of the project proponent for each site-specific project. For those projects not undertaken by, or otherwise subject to the jurisdiction of, DWR or the Board, the project proponent generally can and should implement all applicable and appropriate mitigation measures. The project proponent is the entity with primary responsibility for implementing specific future projects and may include DWR; the Board; reclamation districts; local flood control agencies; and other federal, State, or local agencies. Because various agencies may ultimately be responsible for implementing (or ensuring implementation of) mitigation measures identified in this PEIR, the text describing mitigation measures below does not refer directly to DWR but instead refers to the “project proponent.” This term is used to represent all potential future entities responsible for implementing, or ensuring implementation of, mitigation measures.

Impact GEO-1 (NTMA): *Exposure of People or Structures to Risks Related to Fault Rupture, Ground Shaking, Liquefaction, or Landslides*

Soil-comprised structures, such as levees and some existing earthen dams in the study area, may be seismically vulnerable under current conditions. Seismic vulnerability relates to the risk of fault rupture, severe ground shaking, and liquefaction. Liquefaction may occur when shallow, saturated, and unconsolidated material is subjected to ground shaking. It commonly occurs where shallow groundwater is present, near surface water bodies, or in filled areas, conditions common throughout the Extended SPA. In steeper upstream portions of the Extended SPA, the risk of landslides also exists. However, no new homes or businesses would be constructed as a part of NTMAs. Therefore, no direct potential would exist for increased exposure of people or structures to risk related to fault rupture, ground shaking, liquefaction, or landslides. The potential for increased exposure of people or structures to such risks as an indirect result of the NTMAs through induced growth is discussed in Section 6.1, “Growth-Inducing Impacts.”

NTMAs such as levee repairs or improvements would increase the levees’ resistance to damage and failure from a seismic event. Improving the levee and flood conveyance systems would stabilize existing levees, and any new structures built (such as setback levees) would meet currently accepted engineering standards, resulting in facilities that would be stronger and more resilient than when they were originally constructed. In addition, constructing setback levees could reduce flood stage peaks in the vicinity of the setback levees and would reduce the potential for erosion to occur. This impact would be beneficial.

No new risks associated with landslides would be created by NTMAs. Constructing setback levees or modifying existing structures in compliance with existing standards and requirements would minimize the risk of levee failure relative to existing conditions. Overall, this impact would be **beneficial**. No mitigation is required.

Impact GEO-2 (NTMA): *Potential Localized Soil Erosion and Inadvertent Permanent Soil Loss as a Result of Construction or Operation and Maintenance Activities*

NTMAs could cause localized soil erosion and inadvertent but permanent soil loss. Either temporary and short-term construction activities, such as constructing access roads and excavating borrow pits, or operations and maintenance activities, such as controlling vegetation, could have this effect. Soil-disturbing activities could result in soil erosion, particularly in the steeper upstream portions of the Extended SPA, or subsidence, particularly in the Delta because of the accelerated oxidation of peat soils. In compliance with existing regulations, a SWPPP would be prepared that would identify BMPs to prevent or minimize erosion, sedimentation, and soil loss that could occur as a result of construction activities. BMPs for NTMAs could include but would not be limited to: scheduling activities to minimize soil disturbance during rain events; using silt fencing, straw bale barriers, fiber rolls, storm drain inlet protection, and hydraulic mulch; preserving vegetation; hydroseeding; and using soil binders.

Using borrow pits during construction for NTMAs would result in permanent soil loss. Through compliance with SMARA (as described previously in Section 3.10.2, “Regulatory Setting”), adverse environmental impacts of excavating borrow pits would be minimized and mined lands would be reclaimed to a usable condition.

In addition, implementing some NTMAs could change the existing hydraulics of the system and increase erosion. See also Impact HYD-1 (NTMA), “Increased Erosion and Siltation from Modifying the Flood Conveyance System,” in Section 3.13, “Hydrology,” for a discussion of the potential for changes in hydrology to affect erosion and siltation.

Overall, through compliance with existing standards and regulations, such as the SWPPP and SMARA, this impact would be **less than significant**. No mitigation is required.

Impact GEO-3 (NTMA): ***Potential Risks of Damage to Infrastructure Associated with Expansive Soils***

Expansive soils are common throughout the Extended SPA and are typically associated with clay-rich soils common on the valley floor. Swelling and shrinking of these soils, associated with wetting and drying cycles, can cause structural damage to infrastructure if the soils are not accounted for in project design and construction. Constructing setback levees and modifying existing structures in compliance with existing standards and requirements, such as those of USACE, the Central Valley Flood Protection Board, and SMARA (discussed above), would sufficiently minimize the risks of structural failure related to the presence of these soils to consider this impact **less than significant**. No mitigation is required.

Impact GEO-4 (NTMA): ***Potential Use of Septic Tanks or Alternative Wastewater Disposal Systems in Areas with Unfavorable Soils***

Septic tanks and alternative wastewater disposal systems would not be used under NTMAs. **No impact** would occur. No mitigation is required.

Impact GEO-5 (NTMA): ***Potential Loss of Availability of a Known Mineral Resource of Value***

Aggregate resources, which are typically located in or near channels or floodplains in the Extended SPA, are the mineral resources most likely to be affected by NTMAs. However, mining activity is generally precluded within or in the immediate vicinity of the footprint of existing structures, such as levees, to preserve the stability of those structures. Although in theory mineral resources could be excavated from the vicinity of a levee as long as the excavation area was filled with compacted soil before the beginning of the next flood season, this approach is not economically feasible for mineral resources found in the Extended SPA. Many NTMAs would occur within the footprint of existing flood protection structures (e.g., slurry cutoff walls through an existing levee), and therefore would not eliminate access to mineral resources. Other NTMAs, such as changing inundation patterns or constructing setback levees, would occur in the immediate vicinity of existing structures, and therefore would also not substantially alter accessibility of mineral resources relative to existing conditions. Therefore, this impact would be **less than significant**. No mitigation is required.

Impact GEO-6 (NTMA): *Possible Damage to or Destruction of Unique Paleontological Resources*

Construction and ground-disturbing activities that occur in materials approximately 11,000 years old or older would have the potential to intersect paleontologically sensitive rock units under SVP guidelines (SVP 1995) that could potentially damage a significant paleontological resource. As stated in Section 3.10.1, "Environmental Setting," remains dated during the past 11,000 years are not considered fossils. Therefore, activities occurring in materials less than 11,000 years old (i.e., deposited during the Holocene age) would have no impact on unique paleontological resources.

As also described in Section 3.10.1, many deposits of the Holocene age are likely to be found in or near waterways, particularly on the valley floor. For example, along the valley floor the Sacramento and San Joaquin rivers typically traverse Holocene deposits within the bounds of their levees (natural or constructed). Therefore, NTMAs in these areas would not be expected to intersect paleontological resources. However, other portions of the Extended SPA are underlain by units formed during the Cenozoic Era (65.5 million years ago to present). Rock formations with known fossil deposits and recognized as paleontologically sensitive under SVP guidelines are located throughout the Extended SPA. As described previously, fossils deposited during the late Mesozoic and Cenozoic eras, when the characteristic alluvial, continental, and marine sediments of the Central Valley were being deposited, are diverse; they include marine, freshwater, and terrestrial flora and fauna. In the upstream portions of the Extended SPA, underlying rock units are typically more deformed and include more volcanic and igneous deposits, which tend to contain fewer paleontologically sensitive rock units.

In keeping with the significance criteria of the SVP (1995), all vertebrate fossils are generally categorized as being of potentially significant scientific value. The potential for NTMAs to damage or destroy paleontologically sensitive rock units would depend on the precise location of disturbance and the amount of land disturbed, including disturbance related to excavating materials for facility construction (e.g., use of borrow sites that may be relatively distant from levee repair, reconstruction, or improvement activities). Such potential would be determined during subsequent site-specific studies. This impact would be **potentially significant**.

Mitigation Measure GEO-6 (NTMA): ***Prepare a Paleontological Resources Assessment and, If Necessary, Conduct Construction Worker Personnel Education, Stop Work If Paleontological Resources Are Encountered during Earthmoving Activities, and Implement Recovery Plan***

If an NTMA involves excavation in native soil (e.g., not imported fill) that has the potential to contain fossils (e.g., greater than 11,000 years old), an assessment of the paleontological sensitivity of rock formations in the excavation area will be conducted. The project proponent will retain the services of a paleontologist to perform an evaluation that includes all of the following:

- A determination of the specific rock formations present at the project site
- A records search of the applicable paleontological resources database to identify past fossil finds in the area
- A field visit (if necessary as determined by the paleontologist)
- A determination as to the paleontological sensitivity of the rock formations in areas proposed for excavation using SVP (1995) guidelines

Studies conducted for past projects in the same area that meet these criteria may be used to fulfill this requirement. No further mitigation will be required for excavation activities in rock formations that are determined to be of low paleontological sensitivity. Before earthmoving activities begin for any project phase in rock units that have moderate to high paleontological sensitivity, the project proponent will retain a qualified paleontologist or archaeologist to train all construction personnel involved in earthmoving activities, including the site superintendent, regarding the following:

- The possibility of encountering fossils

- The appearance and types of fossils likely to be seen during construction

- The proper notification procedures to follow if fossils are encountered

In addition, as determined by the paleontologist in consultation with the project proponent, full-time monitoring during earthmoving activities may be required in areas of high paleontological sensitivity.

If a paleontological resource potentially qualifying as unique or significant (as defined above in “Thresholds of Significance”) is discovered during earthmoving activities, the construction crew will immediately cease work in the vicinity of the find and notify the project proponent. The project proponent will retain a qualified paleontologist to evaluate the resource, and if it is confirmed to qualify as a unique or significant resource, a qualified paleontologist will prepare a recovery plan in accordance with SVP guidelines (1995). The recovery plan may include but will not be limited to further field surveys in the vicinity of the find, sampling and data recovery procedures, museum storage coordination for any specimen recovered, further monitoring of earthmoving activities, and a report of findings. The project proponent will ensure implementation of the recovery plan. Construction activities can resume at locations where unique or significant paleontological resource are discovered after the resource has been recovered and moved from the work site.

Implementing Mitigation Measure GEO-6 (NTMA) would reduce potential impacts on paleontological resources to a **less-than-significant** level because construction workers would be alerted to the possibility of encountering unique paleontological resources, monitoring would occur in areas of high sensitivity, and any unique or significant fossil specimens encountered would be recovered and recorded and would undergo appropriate curation.

3.10.5 Environmental Impacts, Mitigation Measures, and Mitigation Strategies for LTMAs

This section describes the physical effects of LTMAs on hydrologic resources. LTMAs include a continuation of activities described as part of NTMAs and all other actions included in the proposed program, and consist of all of the following types of activities:

- Widening floodways (through setback levees and/or purchase of easements)

- Constructing weirs and bypasses

- Constructing new levees
- Changing operation of existing reservoirs
- Achieving protection of urban areas from a flood event with 0.5 percent risk of occurrence
- Changing policies, guidance, standards, and institutional structures
- Implementing additional and ongoing conservation elements

Actions included in LTMAs are described in more detail in Section 2.4, “Proposed Management Activities.”

Impacts and mitigation measures identified above for NTMAs would also be applicable to many of the LTMAs and are identified below. The NTMA impact discussions and mitigation measures are modified or expanded where appropriate, or new impacts and mitigation measures are included if needed, to address conditions unique to LTMAs. The same approach to future implementation of mitigation measures described above for NTMAs and the use of the term “project proponent” to identify the entity responsible for implementing mitigation measures also apply to LTMAs.

LTMA Impacts and Mitigation Measures

Impact GEO-1 (LTMA): *Exposure of People or Structures to Risks Related to Fault Rupture, Ground Shaking, Liquefaction, or Landslides*

This impact would be similar to Impact GEO-1 (NTMA), described above. LTMAs could occur throughout the study area and could be larger in scale than NTMAs; as a result, this impact has a greater potential to occur than Impact GEO-1 (NTMA). Construction of new facilities or repair/reconstruction of existing facilities using modern engineering standards and techniques would increase the system’s resilience to seismic events. Constructing setback levees or modifying existing structures in compliance with existing standards and requirements would minimize the risk of levee failure relative to existing conditions. These impacts would be beneficial. No new risks associated with landslides would be created by LTMAs.

Overall, this impact would be **beneficial**. No mitigation is required.

Impact GEO-2 (LTMA): *Potential Localized Soil Erosion and Inadvertent Permanent Soil Loss as a Result of Construction or Operation and Maintenance Activities*

This impact would be similar to Impact GEO-2 (NTMA), described above. LTMAs have the potential to occur throughout the study area and to be larger in scale than NTMAs; therefore, this impact has a greater potential to occur than Impact GEO-2 (NTMA). Effects would include localized soil erosion and inadvertent permanent soil loss as a result of temporary and short-term construction activities and long-term levee improvements, changes in release timing, and operation and maintenance activities. See also Impact HYD-1 (LTMA), "Increased Erosion and Siltation from Modifying the Flood Conveyance System," and Mitigation Measure HYD-1 (LTMA), "Identify and Implement Measures to Minimize Downstream Erosion and Siltation," in Section 3.13, "Hydrology," for a discussion of the potential for changes in hydrology to affect erosion or siltation. As described above, a SWPPP would be prepared and implemented for construction and operation and maintenance activities that would prevent substantial soil erosion and soil loss; borrow pits would be excavated and reclaimed in a manner compliant with SMARA; and the design of new or improved levees and facilities would comply with existing standards and requirements. Therefore, this impact would be **less than significant**. No mitigation is required.

Impact GEO-3 (LTMA): ***Potential Risks of Damage to Infrastructure Associated with Expansive Soils***

This impact would be similar to Impact GEO-3 (NTMA), described above. LTMAs have the potential to occur throughout the study area and to be larger in scale than NTMAs; therefore, this impact has a greater potential to occur than Impact GEO-3 (NTMA). Widening floodways or constructing new weirs, bypasses, and setback levees and modifying existing structures in compliance with existing standards and requirements would minimize the risks of structural failure associated with the presence of expansive soils. This impact would be **less than significant**. No mitigation is required.

Impact GEO-4 (LTMA): ***Potential Use of Septic Tanks or Alternative Wastewater Disposal Systems in Areas with Unfavorable Soils***

LTMAs include constructing facilities such as pump stations that, depending on their location, could generate wastewater. Although incorporated areas in the study area are typically serviced by existing sewer systems, LTMAs may be constructed in locations where sewers are not available for disposal of wastewater. Such facilities would rely on septic tanks or alternative wastewater disposal systems for this purpose.

Conditions that affect the suitability of soil—and therefore the location for constructing, operating, and maintaining a wastewater disposal system—

include saturated hydraulic conductivity (a measurement of soil permeability), depth to groundwater, depth to bedrock or hardpan, and frequency and depth of flooding. For example, shallow depth to bedrock can interfere with septic tank installation, and steep slopes may cause lateral seepage and surfacing of effluent in downslope areas. Other unfavorable conditions that may be present include active subsidence or the presence of a shallow soil hardpan (both of which interfere with septic system installation and maintenance) and a shallow groundwater table (which increases the potential for groundwater contamination).

Where possible, facilities that would generate wastewater would be sited to avoid areas with unfavorable soil conditions. If such facilities would be located in an area not serviced by an existing sewer system, wastewater disposal systems would be designed to comply with all relevant federal, State, and local regulations governing their design, construction, operation, and maintenance. Constructing wastewater disposal systems in compliance with existing standards and requirements would create minimal risk associated with these facilities. Therefore, this impact would be **less than significant**. No mitigation is required.

Impact GEO-5 (LTMA): *Potential Loss of Availability of a Known Mineral Resource of Value*

This impact would be similar to Impact GEO-5 (NTMA), described above. Release patterns and associated inundation patterns would be changed, existing facilities would be improved, and setback levees would be constructed within the existing footprint or in the immediate vicinity of the footprint of existing structures. Mining activity is generally precluded within or in the immediate vicinity of the footprint of existing structures, such as levees, to preserve the stability of those structures. Therefore, these actions would not eliminate access to mineral resources. However, LTMAs include widening floodways and constructing weirs, new bypasses, or setback levees outside the existing footprint or the immediate vicinity of the footprint of existing structures. The availability of known mineral resources could be lost because inundation or construction of new bypasses or setback levees or the purchase of easements could permanently prevent access to those resources. Whether and to what extent the availability of mineral resources would be lost would depend on what specific activities would be required and where they would occur. This effect would first occur during construction and would result in temporary loss of access to the minerals located underground. This impact would be **potentially significant**.

Mitigation Measure GEO-5 (LTMA): *Minimize Loss of Mineral Resources through Siting and Design*

When designing bypasses or setback levees or purchasing easements, the project proponent will consider a range of locations and configurations to minimize the potential to eliminate access to locally valuable mineral resources.

Implementing this mitigation measure would reduce Impact GEO-6 (LTMA), but not necessarily to a less-than-significant level in all cases because it may not be possible to construct bypasses and setback levees to avoid mineral resources or to prevent access to locally valuable mineral resources through continual inundation or permanent easements. Therefore, Impact GEO-5 (LTMA) would be **potentially significant and unavoidable**.

Impact GEO-6 (LTMA): *Possible Damage to or Destruction of Unique Paleontological Resources*

This impact would be similar to Impact GEO-6 (NTMA), described above. LTMAs have the potential to occur throughout the study area and to be larger in scale than NTMAs; therefore, this impact has a greater potential to occur than Impact GEO-6 (NTMA). Although some LTMAs may be determined to have no impact or less-than-significant impacts, others may have the potential to result in a significant impact. The potential for LTMAs to damage or destroy unique or significant paleontological resources would depend on the precise location of disturbance and the amount of land disturbed, including disturbance related to excavating materials for construction of weirs, bypasses, or setback levees. Such potential would be determined during subsequent site-specific studies. This impact would be **potentially significant**.

Mitigation Measure GEO-6 (LTMA): *Implement Mitigation Measure GEO-6 (NTMA), "Prepare a Paleontological Resources Assessment and, If Necessary, Conduct Construction Worker Personnel Education, Stop Work If Paleontological Resources Are Encountered during Earthmoving Activities, and Implement Recovery Plan"*

Implementing this mitigation measure would reduce Impact GEO-6 (LTMA) to a **less-than-significant** level.

LTMA Impact Discussions and Mitigation Strategies

The impacts of the proposed program's NTMAs and LTMAs related to geology, soils, and seismicity (including mineral and paleontological resources) and the associated mitigation measures are thoroughly described and evaluated above. The general narrative descriptions of additional LTMA impacts and mitigation strategies for those impacts that are included in other sections of this draft PEIR are not required for geology, soils, and seismicity (including mineral and paleontological resources).